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REPORT ON POLLUTION OF INTERSTATE WATERS OF THE MOUTH OF THE SAVANNAH RIVER GEORGIA-SOUTH CAROLINA

ROBERT A. TAFT SANITARY ENGINEERING CENTER
CINCINNATI, OHIO

NOVEMBER 1964

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REPORT ON POLLUTION OF INTERSTATE WATERS OF THE MOUTH OF THE SAVANNAH RIVER GEORGIA-SOUTH CAROLINA

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U. S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
ROBERT A. TAFT SANITARY ENGINEERING CENTER

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The lower 28 miles of the Savannah River flowing past the industrial area of Chatham County and Savannah and into the Atlantic Ocean were surveyed. These waters once supported commercial American shad and oyster fisheries, but because of pollution discharged to the river, the waters were closed to shellfishing. Data are presented on water uses, sources of wastes (sewage, industrial wastes, oxygen-demanding wastes, and acid wastes), dispersion of wastes, bacterial pollution, oxygen demand and dissolved oxygen, oil pollution, and radioactivity.

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*Water pollution sampling	Bacteria
*Water quality	Radioactive contaminants
Recreation	Oil pollution
Fishes	Acid mine drainage
Sewage disposal	Savannah(Georgia)
Industrial wastes	South Carolina

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REPORT ON
POLLUTION OF INTERSTATE WATERS
OF THE
MOUTH OF THE SAVANNAH RIVER
GEORGIA-SOUTH CAROLINA

SUMMARY AND CONCLUSIONS

The Savannah River is one of the principal interstate streams in the southeastern States, and for approximately 310 miles it forms the border between Georgia and South Carolina.

This report deals with the lower 28 miles of the river flowing past the industrial area of Chatham County and the city of Savannah and into the Atlantic Ocean near Savannah Beach. Portions of the connecting tidal waters of the New, Wright, and Cooper rivers in South Carolina, are included.

The tidal waters of the Savannah River are used for navigation, commerce, industrial water supply, recreational boating, sport fishing and water contact sports such as swimming and water skiing. The main channels also are used for sewage and industrial waste disposal. These waters once supported commercial American shad and oyster fisheries, but because of pollution discharged to the river, the waters were closed to shellfishing, and these industries no longer exist.

Sewage from a sewered area totaling about 146,000 population is discharged to the Savannah River. One-fifth of the sewage receives primary treatment, which reduces the total bacterial loading by about 10 percent, and the oxygen demand by 7 percent. The remaining four-fifths of the sewage enters the river raw. About 80 percent of the waste constituents of sewage entering the river, or an oxygen demand population equivalent of approximately 108,000, is included in the raw sewage discharged from the city of Savannah. About 10 percent, having a population equivalent of approximately 15,000, is discharged by the Savannah Beach primary sewage treatment plant, and the remaining 8 percent is discharged by other jurisdictions shown in the table of estimated sewage characteristics.

In addition, industries discharge process wastes, cooling water, and chemical wastes, which include oxygen demanding materials estimated to be equivalent to those in raw sewage from a sewered population of approximately 1,000,000. About 90 percent of the oxygen consuming materials in the industrial wastes is discharged by the pulp and paper mills. An estimated 78 percent, having a population equivalent of 810,000, is discharged by Union Bag-Camp Paper Corporation; 12 percent, with a population equivalent of 130,000, by Continental Can Company; and the remaining 10 percent is discharged by the other six industries shown in the table of industrial wastes characteristics.

The combination of sewage and industrial wastes causes pollution of the Savannah River. Bacterial pollution was most severe in the Georgia waters of the main channel (S-14) near the sewage discharges from the city of Savannah, where the average total coliform density

of 31,800 MPN/100 ml exceeded six times the commonly used 5,000 MPN/100 ml general recreation objective. Ten percent of the samples from this station contained more than 62,000 MPN/100 ml, which is more than 12 times the objective.

In the interstate waters near the mouth of Back River (S-11.5-0.5) the average 10,300 MPN/100 ml total coliform density was twice the objective. Ten percent of the samples exceeded 22,000 MPN/100 ml, which is more than 4 times the objective.

The waters flowing past R.M. 10 in Georgia, towards the interstate waters one-half mile downstream, also exceeded the objective with an average of 7,250 MPN/100 ml and 10 percent of the samples contained more than 14,000 MPN/100 ml, or almost 3 times the 5,000 MPN/100 ml objective.

The average coliform densities at sampling stations in the interstate and intrastate reaches of the North Channel from below River Mile S-10.0 to the mouth were reduced below the 5,000 MPN/100 ml standard for general recreation. The 10 percent values, however, equalled or exceeded the objective in 8 of the 10 miles. Coliform bacteria in these waters contributed to pollution of the adjoining Wright and New rivers in South Carolina where total coliform densities exceeded the allowable limits for shellfishing.

The median total coliform density for approved shellfish harvesting areas should not exceed 70 MPN/100 ml, and a density of 230 MPN/100 ml should not be exceeded in more than 10 percent of the samples. These objectives for shellfish waters were exceeded throughout

the entire reach of the Savannah River included in this study.

The bacterial quality of portions of the Wright and New rivers in South Carolina exceeded the 70 MPN/100 ml total coliform bacteria limiting objective for shellfishing. The median total coliform densities in the Wright River ranging from 175 MPN/100 ml 4-1/2 miles upstream to 380 MPN/100 ml at the mouth were from 2.5 to 5.5 times the objective for shellfishing. The total coliform densities at these stations exceeded 230 MPN/100 ml from 42 to 73 percent of the time.

In 4 of the 6 miles of the New River under study, the total coliform densities slightly exceeded the median objective as they ranged from 80 to 120 MPN/100 ml. The total coliform densities at all New River stations exceeded the 230 MPN/100 ml decile limit from 14 to 28 percent of the time.

Calculations based on data from dye studies of the U. S. Army Corps of Engineers Savannah Harbor Hydraulic Model indicate that about 99 percent of the sewage associated bacterial pollution in the main channel, and from 85 to 94 percent in the Wright River can be attributed to sewage from the city of Savannah. In the New River, from 57 to 86 percent are attributed to the city of Savannah, and 14 to 43 percent to the unchlorinated effluent from the Savannah Beach sewage treatment plant.

These bacterial densities, which include bacteria of fecal origin, indicate health hazards in the use of certain of these waters for recreation and shellfishing. Therefore the States of Georgia and South Carolina have closed much of this area to shellfishing.

Although neither Georgia nor South Carolina has established D.O. standards for the Savannah Estuary, in other classified waters in the State the South Carolina Water Pollution Control Authority has established 4.0 mg/l of dissolved oxygen as the minimum objective for the propagation of a well balanced population of fish and other desirable aquatic life.

The D.O. in the Savannah River was frequently less than this 4.0 mg/l D.O. objective at all sampling stations in the entire 21-mile reach of intrastate and interstate water from S-19 at the Chatham County industrial complex to S-2 at the mouth of the river.

At S-5, in the interstate waters near Fields Cut, the D.O. averaged 2.8 mg/l and the minimum values ranged from 1.1 near the surface to 1.6 near the bottom. At this station, 78 percent of the samples contained less than 4.0 mg/l; 60 percent contained less than 3.0 mg/l and 21 percent contained less than 2.0 mg/l of D.O.

Oxygen-demanding pollution entering the river in Georgia reduced the dissolved oxygen levels of waters in Georgia and South Carolina below the generally accepted water quality objectives for the propagation of fish and other desirable forms of aquatic life.

Sewage and industrial wastes discharged to the Savannah River Estuary from Georgia cause pollution of interstate waters in Savannah River Estuary, which endangers the health or welfare of persons in South Carolina, and therefore is subject to abatement under the provisions of the Federal Water Pollution Control Act.

INTRODUCTION

On the basis of reports, surveys, or studies, having reason to believe that pollution of the Savannah River Estuary originating in Georgia was endangering the health or welfare of persons in South Carolina, the Secretary of the Department of Health, Education, and Welfare called a conference of the state water pollution control agencies of Georgia and South Carolina, and the Department of Health, Education, and Welfare.

This report on pollution of interstate waters of the Savannah River Estuary is based primarily on data obtained by the Department through a field study conducted during the period August 6 through August 27, 1963. The Chatham County Health Department performed the bacteriological examinations on samples collected during this survey.

The manner in which wastes are dispersed throughout the estuary by the undulating flood and ebb tides was determined from Savannah Harbor Hydraulic Model studies conducted by the U. S. Army Engineer Waterways Experiment Station at Vicksburg, Mississippi.

Supplementary information was provided by the Georgia State Department of Public Health, South Carolina Water Pollution Control Authority, Chatham County Health Department, City of Savannah, and representatives of industries and municipalities.

Data obtained during the October 21 - November 9, 1962 preliminary survey was used to select appropriate sampling stations, determine sampling period intervals, and organize the field study of this complex tidal estuary.

The whole-hearted and invaluable cooperation of the numerous agencies and individuals is gratefully acknowledged.

THE AREA

The Savannah River is one of the principal interstate streams of the southeastern states. Formed by the Tugaloo and Seneca rivers, and impounded in the Hartwell and Clark Hill reservoirs in northern Georgia and South Carolina, the river flows past Augusta, Georgia, and the Savannah River plant of the Atomic Energy Commission and continues southeasterly on its way out to the sea below Savannah, Georgia. It forms the boundary between Georgia and South Carolina for approximately 310 miles.

The study area covered by this report (Figure 1) includes the lower 28 miles in the States of Georgia and South Carolina, and the connecting Wright, New and Cooper rivers in the State of South Carolina. The uppermost sampling station is located at River Mile (R.M.) S-28, about seven river miles upstream from the northern limits of the 5-mile Chatham County industrial complex, which

FIGURE NO. 1

LOCATION MAP

SURVEY & DYE STUDY STATIONS

SAVANNAH RIVER ESTUARY

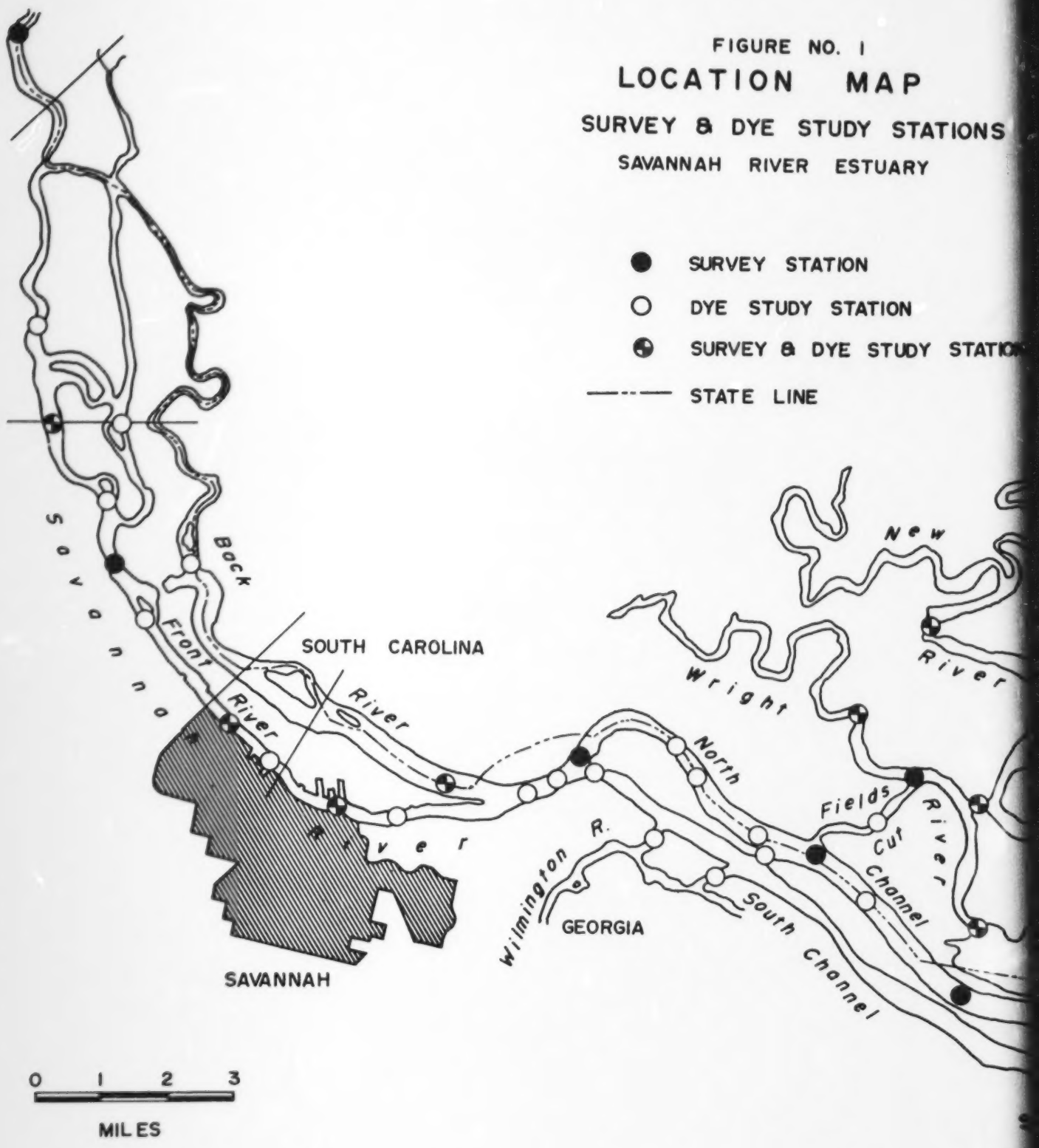

FIGURE NO. 1

LOCATION MAP

SURVEY & DYE STUDY STATIONS

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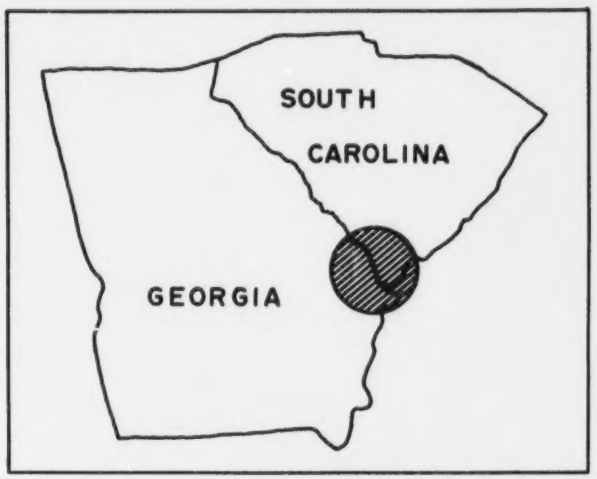
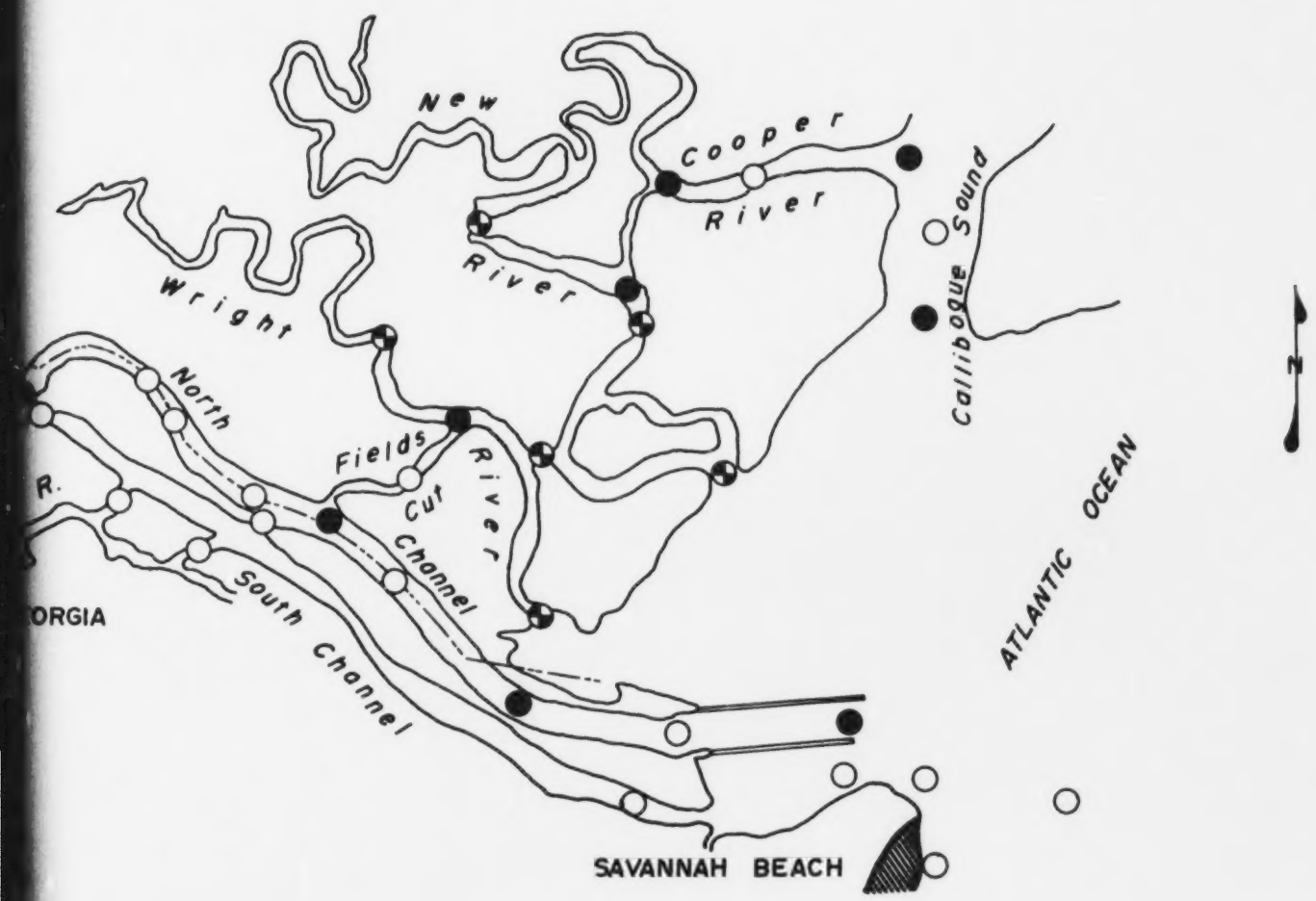


● SURVEY STATION

○ DYE STUDY STATION

◓ SURVEY & DYE STUDY STATION

——·—— STATE LINE



extends from about R.M. 21 down to R.M. 16. The river flows past the center of the city of Savannah near R.M. 14.5, and then branches off into North and South Channels at R.M. 10.0. At a point about 5 miles above the mouth, the intercoastal waterway connecting the Wright, New and Cooper rivers branches off from the North Channel through Fields Cut. Rock jetties define the North Channel for about 2 miles out into the ocean from the Fort Pulaski National Monument, which is designated as R.M. 0.

The Front River channel of the Savannah River bordering the city of Savannah, Georgia, is located in the State of Georgia. In this region, Back River forms the interstate boundary to a point just above its confluence with Front River. From this point, the State boundary follows the cut north of Barnwell Island for about 2 miles, and then the center of the North Channel of the Savannah River for about 7 miles to Horseshoe Shoals, where it veers to the east and out into the Atlantic Ocean.

The Savannah River is the nucleus for economic, commercial, industrial, and community activity and growth of the city of Savannah and Chatham County.

The city of Savannah, Georgia with a population of about 150,000 is by far the largest community in the area. Savannah Beach, Georgia, a resort area located along the ocean front southeast of

the river mouth, attracts an estimated 25,000 population during the recreational period of the year. Other Georgia communities, including Chatham City, Garden City, and Port Wentworth, adjoin the river.

Industries located in the area include pulp and paper mills, a sugar refinery, asphalt roofing and pressure creosoting plants, marine terminals for asphalt and flammable petroleum products, and plants producing naval stores, fertilizers and chemical products.

WATER USES

The main channels of the Savannah River in the study area are used principally for navigation, commerce, boating, industrial water supply, and waste disposal. In former years, the river and adjacent waters were used for commercial fishing and shellfish harvesting. The waters off the main channel and along the ocean front are used extensively for recreational boating, fishing, swimming, and water skiing.

INDUSTRIAL WATER SUPPLY

Savannah River water in the study area is used extensively as a source of industrial cooling water. The total amount used for this purpose is estimated to exceed 50,000,000 gallons per day. In addition to water obtained from other sources, Union Bag-Camp, Continental Can, Savannah Sugar Refining, and American Cyanamid plants each use about 10,000,000 gallons of river water per day.

NAVIGATION

Ocean going vessels, engaged in world commerce, navigate the Savannah River on their way to and from the city of Savannah and

the industrial area in Chatham County. The U. S. Army Corps of Engineers operates dredges and work boats on the river during their continuing program of river channel maintenance. Smaller craft cruise the river and connecting streams in the intercoastal waterway. These boating activities involve contact of individuals with the water in the estuary.

COMMERCIAL FISHING

At one time commercial fishermen fished the Savannah River extensively for the American shad. It is reported that in recent years the flesh of the fish caught in this area was tainted with objectionable tastes and commercial buyers were reluctant to handle Savannah River fish. The commercial fishermen gradually moved to other fishing areas and the Savannah River no longer supports a commercial shad fishery.

Oysters abound in the tidal waters of the Savannah River Estuary. Some 30 years ago, this area supported a commercial shellfishing industry. Parts of the Savannah River and adjacent tidal waters are polluted by sewage, and because of the health hazard associated with the consumption of raw oysters harvested from waters containing bacteria from sewage pollution, these areas in Georgia and South Carolina have been closed to shellfishing by the State health departments, and this commercial fishery no longer exists.

The waters of the sound outside the mouth of the river are

fished extensively for shrimp and commercial trawlers continue to traverse the sound while engaged in this industry.

RECREATION

The tidal waters of the Savannah River are used for sport fishing and recreational boating, and areas of the connecting streams and the ocean front beaches, principally in Georgia, are used for water contact sports such as swimming and water skiing. Hundreds of boats, moored in these areas, cruise these waters on the way out to the deep sea fishing areas in the Atlantic Ocean.

SOURCES OF WASTES

Raw and partially treated sewage and industrial wastes cause excessive pollution of certain reaches of the Savannah River in Georgia and South Carolina. The sewage discharges also cause excessive bacterial pollution of certain reaches of the Wright River and the New River in South Carolina.

SEWAGE

Sewage contains numerous obnoxious constituents which may have adverse effects on water quality and uses. The effects of sewage pollution on the Savannah River Estuary have been evaluated primarily on the basis of bacteria and oxygen demanding materials. The content of sewage from either untreated or treated sources may be described in terms of bacterial and oxygen demand population equivalents. The population equivalents are the sewered populations that would produce raw sewage having equivalent quantities of bacteria or oxygen demanding substances.

All of the known sewage discharges enter the tidal waters from Savannah, Georgia, metropolitan area and Savannah Beach. The estimated sewage characteristics, shown in Table 1, are based on information provided by representatives of the city of Savannah and the Chatham County Health Department. The total sewered population is estimated

ESTIMATED SEWAGE CHARACTERISTICS

August, 1963 Survey
Savannah River Estuary

Table No. 1

Jurisdiction	Receiving Stream	Type of System*	Type of Treatment	Population Served	Population Equivalents Discharged			
					Oxygen Demand Number	% of Total	Bacteria Number	% of Total
I. Discharges Entering Savannah River or Canals Flowing to the Savannah River								
Port Wentworth Corp.	Savannah River (From S-21 to S-20)	S	None	3,700	3,700	2.7	3,700	2.8
Travis Field	Pipemakers Canal (Entering River at S-18.5)	S	Primary (Imhoff Tank)	970	640	0.5	480	0.4
Garden City (Untreated Part)	Pipemakers Canal (Entering River at S-18.5)	S	None	5,200	5,200	3.8	5,200	4.0
Chatham City (Treated Garden City Area)	Dundee Canal (Entering River at S-17.4)	S	Primary	1,800	1,200	0.9	900	0.7
Ruberoid Co. (Domestic Sewage)	Dundee Canal (Entering River at S-17.4)	S	Primary (Spiragester)	180	120	0.1	90	0.1
City of Savannah (Untreated Part)	Savannah River (From S-16 to S-13)	C	None	108,000	108,000	79.6	108,000	82.4
Cloverdale	Springfield-Savannah-Ogeechee Canal (Entering at S-15)	S	Secondary (Oxidation Pond)	1,500	150	0.1	150	0.1
Atlantic Cement (Domestic Sewage)	Back River (at RM-15)	S	Secondary (Cavitette)	15	0+	0	0+	0
Savannah Beach (Summer Population)	Mouth of South Channel	C	Primary (Sed. & Digestion)	25,000	16,700	12.3	12,500	9.5
Total to Savannah River				146,365	135,710	100.0	131,020	100.0

ESTIMATED SEWAGE CHARACTERISTICS

August, 1963 Survey
Savannah River Estuary

Table No. 1
Cont.

Jurisdiction	Receiving Stream	Type of System*	Type of Treatment	Population Served	Population Equivalents Discharged			
					Oxygen Demand Number	Oxygen Demand % of Total	Bacteria Number	Bacteria % of Total
II. Discharges to Tributaries Not Entering Savannah River								
Bacon Park	Vernon River	S	Secondary & Chlorination	38,000	11,400	88.1	380	40.0
Wilshire Estates	Vernon River	S	Secondary (Oxidation Pond)	1,500	150	1.2	150	15.8
Hunter Air Force Base	Little Ogeechee R.	S	Secondary & Chlorination	5,000	1,000	7.8	50	5.3
Windsor Forest	Little Ogeechee R.	S	Secondary (Oxidation Pond)	3,500	350	2.7	350	36.8
Thunderbolt	Land & Wilmington R.	-	Septic Tanks & Drain Fields (Some Direct to River)	Undet.	-	-	-	-
Islandwood	Wilmington R.	S	Secondary (Oxidation Pond)	200	20	0.2	20	2.1
Total to Tributaries				48,200	12,920	100.0	950	100.0

* Type of System: S = Separate Sanitary Sewers

C = Combined Sanitary & Storm Sewers

to be 194,000. Approximately 25 percent of this total sewered population is located in areas that are drained toward the intrastate Vernon, Wilmington, and Little Ogeechee rivers in the State of Georgia. Raw and treated sewage from the remaining 75 percent of the sewered population discharges to the Savannah River, which flows along the interstate boundary between Georgia and South Carolina below River Mile 10, and is connected to the Wright and New rivers in South Carolina. This 75 percent includes the treated sewage from Savannah Beach, which is discharged to the Georgia waters of the Ocean near the mouth of South Channel and which, in turn, is distributed throughout both Georgia and South Carolina waters by tidal currents.

The sewage from that quarter of the total sewered population which discharges into the Georgia intrastate waters receives secondary treatment, with the exception of an undetermined portion of the raw sewage which is discharged directly to the Wilmington River from Thunderbolt. Two jurisdictions, Bacon Park and Hunter Air Force Base, chlorinate the treated sewage.

Approximately one-fifth of the sewage from that three-quarters of the total sewered population which discharges to the Savannah River receives primary treatment. The areas served by these plants include Savannah Beach, Chatham City, and Travis Field. Sewage from Cloverdale, amounting to approximately 1 percent of the total flow reaching the Savannah River, receives secondary treatment.

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Approximately one-fifth of the sewage from that three-quarters of the total sewered population which discharges to the Savannah River receives primary treatment. The areas served by these plants include Savannah Beach, Chatham City, and Travis Field. Sewage from Cloverdale, amounting to approximately 1 percent of the total flow reaching the Savannah River, receives secondary treatment.

Properly designed and operated primary sewage treatment plants can remove approximately one-third of the oxygen-demanding materials, and about one-half of the bacteria from raw sewage. Secondary sewage treatment plants, which are essentially biological processes, can remove approximately 90 percent of the oxygen-consuming material, and 90 to 99 percent of the bacteria from raw sewage. Chlorination of treatment plant effluents can achieve further major reductions in the bacterial content of the sewage, but accomplishes little additional reduction in other constituents. The combination of secondary biological treatment and chlorination can accomplish the maximum reduction of all pollutional constituents that are feasible by present conventional sewage treatment methods, but in no case is 100 percent removal effected. Some residual materials remain in effluents from even the most efficient types of treatment facilities.

Bacteria

The estimated characteristics of sewage from the entire Savannah Beach and city of Savannah metropolitan area are shown in Table 1. The following discussions of bacteria and oxygen demand of the sewage, and subsequently of industrial wastes, cover only those portions of the wastes that enter the Savannah River or South Channel, and which are in turn carried into the interstate South Carolina waters.

The total sewered population of the area draining toward the interstate waters is estimated to be 146,000. The treatment presently

provided is estimated to reduce the overall bacterial content of the sewage by about 10 percent, leaving bacteria equivalent to those in the raw sewage from 131,000 persons to enter the waters.

The estimated bacterial loads from the various sources of sewage, with estimated allowances for any treatment provided, are presented in Section I of Table 1. The loads are expressed in terms of bacterial population equivalents (BPE). A bacterial population equivalent may be defined as the quantity of coliform bacteria contributed to a stream daily by the untreated sewage discharge from one person. The data in Section I of Table 1 are shown graphically in Figure 2. This figure provides a visual impression of the relative proportion of the total bacterial load discharged from each known source of sewage. The diameters of the circles are in proportion to the loads from the various jurisdictions. The circle in the legend, representing the scale of the drawing, is equivalent to the bacterial contribution of raw sewage from 25,000 persons.

The untreated portion of the raw sewage from the city of Savannah, entering the Savannah River between River Mile S-16 and S-13, is the largest source of bacterial pollution. The 108,000 estimated population equivalent from this source amounts to approximately 80 percent, or more than three-quarters of the total from all sources.

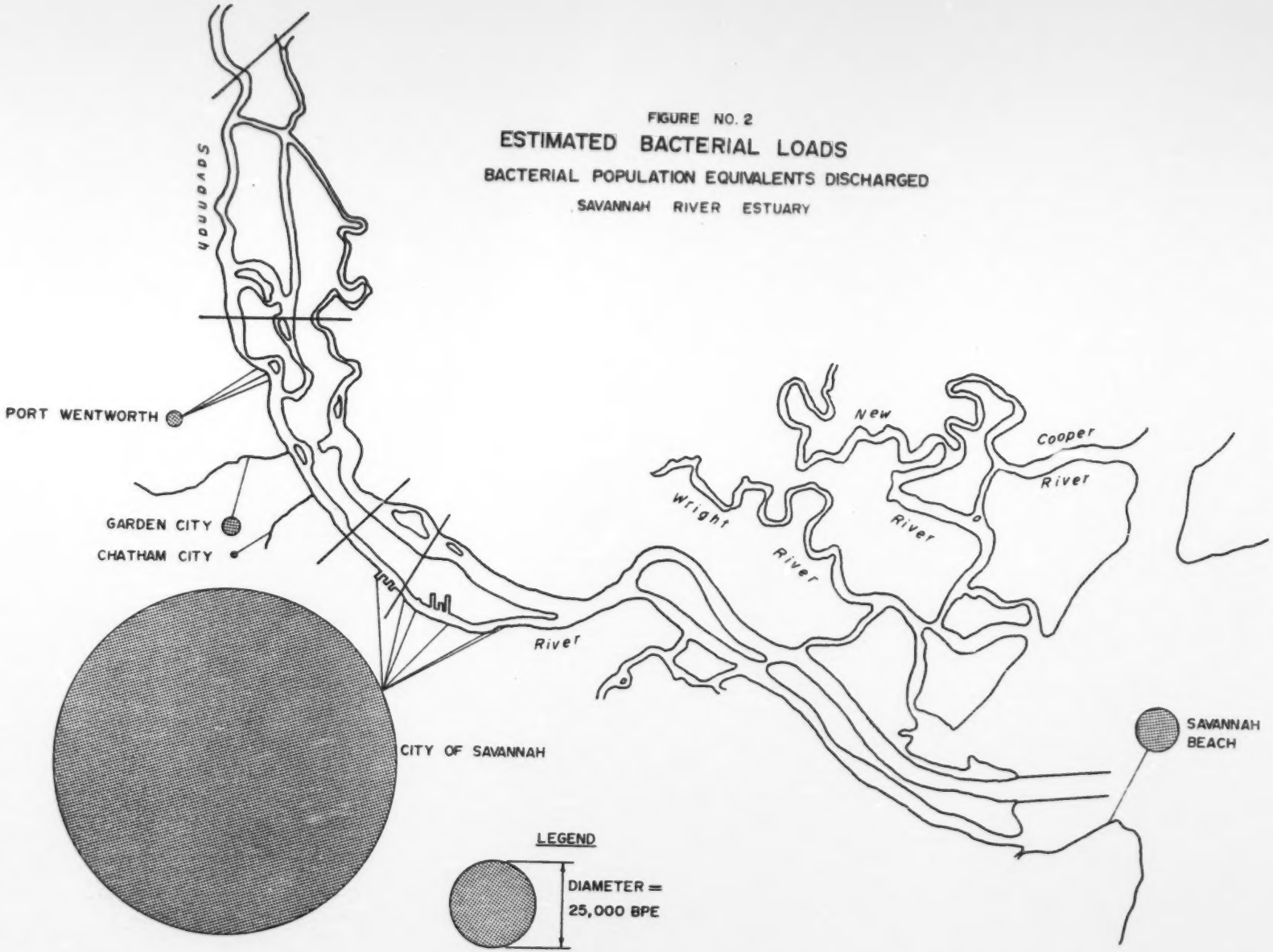
Savannah Beach, providing inadequate primary sewage treatment for an estimated 25,000 summer population, is the second single largest source. Raw sewage is periodically bypassed around the

FIGURE NO. 2

ESTIMATED BACTERIAL LOADS

BACTERIAL POPULATION EQUIVALENTS DISCHARGED

SAVANNAH RIVER ESTUARY



treatment plant and breaks in the outfall sewer release sewage directly on the shore instead of diffusing all wastes into the deeper waters. Sewage is not chlorinated or otherwise disinfected. It is estimated that the effluent from this primary sewage treatment plant, discharged near the mouth of South Channel, contains approximately 12,500 bacterial population equivalents, or 10 percent of the total from all sources.

All other discharges combined, including approximately 3 percent from Port Wentworth Corporation, 4 percent from the untreated portion of Garden City sewage, and the other smaller sources listed in the table but not illustrated on the drawing, amount to 8 percent of the total bacterial load.

Oxygen Demand

The raw sewage from all sources is estimated to exert a 5-day biochemical oxygen demand (BOD) equal to a population equivalent (PE) of 146,000. The treatment provided reduces the combined oxygen demand only 7 percent, leaving a PE of 136,000, or 93 percent of the total, to be discharged to the receiving streams.

Of the oxygen demand from sewage sources, approximately 80 percent is accounted for by the raw sewage from the city of Savannah, and 12 percent by the effluent from the Savannah Beach primary sewage treatment plant. The other jurisdictions shown in Part I of Table 1, and including Port Wentworth Corporation and Garden City, are responsible for the remaining 8 percent of the total oxygen demand load.

INDUSTRIAL WASTES

The industrial wastes discharged to the Savannah Estuary add little to the total bacterial pollution of the waters. Domestic sewage is discharged without treatment at some of the plants, but most of the employees live in nearby sewered areas, and the bacterial population equivalents of sewage from these sources are included in the preceding discussion of bacterial pollution from sewage sources. The Ruberoid Company provides primary, and the Atlantic Cement Company provides secondary treatment for domestic sewage from these plants which employ a total of approximately 200 people.

This section of the report covers the pollutional effect of oxygen-demanding materials discharged to the river.

Information concerning industrial waste characteristics was provided by representatives of the industries located in the Savannah Harbor area. The estimated industrial wastes characteristics of the eight industries discharging oxygen-demanding materials to the river are shown in Table 2. A table showing the amount and nature of wastes from other industries discharging cooling water or industrial wastes, but not contributing significantly to the oxygen demand of the river, is shown in Table 3. The location of marine terminals storing inflammable and asphalt products is shown in Table 4.

Table No. 2

ESTIMATED INDUSTRIAL WASTE CHARACTERISTICS
(Oxygen Demand of Wastes Discharged to the River)

August, 1963 Survey
Savannah River Estuary

Plant	Classification	Receiving Stream	River Mile	Type of Treatment	Oxygen Demand Population Equivalents Discharged Number	% of Total
Continental Can Co., Inc.	Paper Mill	Savannah River	20.9	Save-all	130,200	12.7
Savannah Sugar Refinery Corp.	Sugar Refining	Savannah River	19.8	None	30,000	2.9
The Ruberoid Company	Asphalt Roofing & Felt	Dundee Canal to River	17.4	Save-alls	4,500	0.4
Hercules Powder Company	Naval Stores & Tall Oil	Dundee Canal to River	17.4	Skimmer	3,900	0.4
Certain-Teed Product Corp.	Asphalt Roofing & Felt	Savannah River	17.3	None	24,000	2.3
Union Bag-Camp Paper Corp.	Paper Mill	Savannah River	16.6	Save-all & Skimmer	810,000	78.6
Wesson Division, Hunt Food & Industry, Inc.	Food Products	Savannah River	16.2	Oil Separators	26,000	2.5
Meddin Packing Company	Packinghouse	Savannah & Ogeechee Canal to River	15.0	None	1,740	0.2
Total to Savannah River					1,030,340	100.0

Table No. 3

Industries Discharging Cooling Water or Industrial Wastes,
But Not Contributing Significantly to the Oxygen Demand of the River
August, 1963 Survey
Savannah River Estuary

Plant & Classification	Stream & River Mile	Nature of Discharge	Flow MGD
Atlantic Creosoting Co. Pressure Creosoting	Savannah River at S-19.9	2,970 ppb phenol (1.21 lbs/day	0.05
Southern Nitrogen Co., Inc. Synthetic Nitrogen	Swamp leading to the Savannah River at S-19.4	3 lbs. NH_4NO_3/day	
General Chemical Div. Allied Chemical Corp. Liquid Alum	Pipemakers Canal (Entering River at S-18.5)	Equipment washing (Waste mud is ponded)	0.002
American Agricultural Chem. Superphosphate	Dundee Canal (Entering River at S-17.4)	Cooling water	
American Oil Co. Asphalt Roofing	Savannah River at S-17.1	Approx. 57 ppb phenol Approx. 7 ppm oil	3.9
Johns-Manville Products Corp. Asphalt Roofing	Savannah River at S-17	Settled cooling water	0.29
Virginia-Carolina Chem. Corp. Superphosphate	Savannah River at S-16.2	Est. 750 lbs/day of F_2	0.11
Southern Fertilizer & Chemical Co. Superphosphate	Savannah River at S-14.5	Cooling water	
Southern States Phosphate & Fert.Co. Superphosphate	Savannah River at S-13	Cooling water	
American Cyanamid Co. Titanium Dioxide	Savannah River at S-10.5	690,000 lbs/day of H_2SO_4 to ponds for controlled disch.	5.0

Table No. 4

LOCATION OF MARINE TERMINALS
August, 1963 Survey
Savannah River Estuary

Industry & Classification	Receiving Stream	River Mile
Inflammable Products		
Southern Oil Co.	Savannah River	17.7
American Oil Co.	Savannah River	17.1
Colonial Oil Co.	Savannah River	15.7
Gulf Oil Corp.	Savannah River	14.6
Atlantic Refining Co.	Savannah River	11.7
The Pure Oil Co.	Savannah River	11.6
Standard Oil Co.	Savannah River	11.5
Asphalt		
American Bitumuls & Asphalt Co.	Savannah River	19.4
Savannah Terminal	Savannah River	17.7

Oxygen Demand

The industrial wastes of the study area have a total estimated PE of 1,000,000. The relative sizes of the individual oxygen demanding loads from industry are shown on Table 5.

The waste discharge from Union Bag-Camp Paper Corporation, located at R.M. S-16.6 just north of the Savannah city limits, is the largest single source of oxygen-demanding pollution. This kraft pulp and paper mill, producing from 2600 to 2700 tons of air-dried pulp per day, and employing about 5200 persons, is one of the largest plants of its type in the world. Principal products are kraft pulp, unbleached paper and paperboard, crude sulfate tall oil, and turpentine. Waste control consists generally of white water re-use and save-alls for fiber recovery in the paper mill, and clarifiers for removal and recovery of floatable waste oils from the tall oil operation. Domestic sewage from plant employees enters the process lines, and seven separate outfalls discharge wastes to the river. The industrial wastes from this plant, with a total estimated population equivalent of 810,000, comprised 79 percent of the total industrial waste loading.

The Continental Can Company, Inc., located at R.M. S-20.9, is the second largest source of industrial wastes. This company, employing about 565 people, produces from 575 to 600 tons of air-dried pulp per day, and the principal product is unbleached kraft liner board. Waste control consists of white water re-use and save-alls for fiber recovery. Sanitary sewage from plant employees enters the process sewers. The population equivalent of the industrial wastes entering the river through two sewers is estimated to be 130,000,

Table No. 5

ESTIMATED OXYGEN DEMAND
Industrial Wastes and Sewage

August, 1963 Survey
Savannah River Estuary

Source	Type	Population Equivalents Number	% of Total
Continental Can Co., Inc.	Ind. Waste	130,200	11.1
Port Wentworth Corp.	Sewage	3,700	0.3
Savannah Sugar Ref. Corp.	Ind. Waste	30,000	2.6
Garden City	Sewage	5,200	0.4
Travis Field	Sewage	640	0.1
Ruberoid Co.	Ind. Waste	4,500	0.4
Hercules Powder Co.	Ind. Waste	3,900	0.3
Chatham City	Sewage	1,200	0.1
Certain-Teed Products Corp.	Ind. Waste	24,000	2.1
Union Bag-Camp Paper Corp.	Ind. Waste	810,000	69.5
City of Savannah	Sewage	108,000	9.3
Wesson Div., Hunt Food & Industry, Inc.	Ind. Waste	26,000	2.2
Meddin Packing Co.	Ind. Waste	1,740	0.2
Cloverdale	Sewage	150	-
Savannah Beach	Sewage	16,700	1.4
Total		1,165,930	100.0

or 13 percent of the total industrial waste loading.

Industries discharging industrial wastes with estimated population equivalents in the range of 24,000 to 30,000 each include the Savannah Sugar Refining Corporation at R.M. S-19.8, the Certain-Teed Products Corporation at R.M. S-17.3, and the Wesson Division of Hunt Food and Industry, Inc., at R.M. S-16.2.

Waste discharges from the Ruberoid Company, the Hercules Powder Company, and the Meddin Packing Company, are estimated to range from 1700 to 4500 population equivalents.

OXYGEN-DEMANDING WASTES - Total from Sewage and Industrial Wastes

The relative sizes of the oxygen-demanding waste loads from each of the individual sources of sewage and industrial wastes loads are posted in Table 5 and shown in Figure 3. Of the total, approximately 1,000,000 PE, or 88.5 percent, was discharged by industries, and approximately 136,000 PE, or 11.5 percent of the load, was domestic sewage. The diameters of the shaded circles represent relative loads from industrial waste sources, and the diameters of the solid circles show the relative loads from sewage sources. The circle in the legend, representing the scale of the drawing, is equivalent to a 200,000 population equivalent oxygen-demanding load.

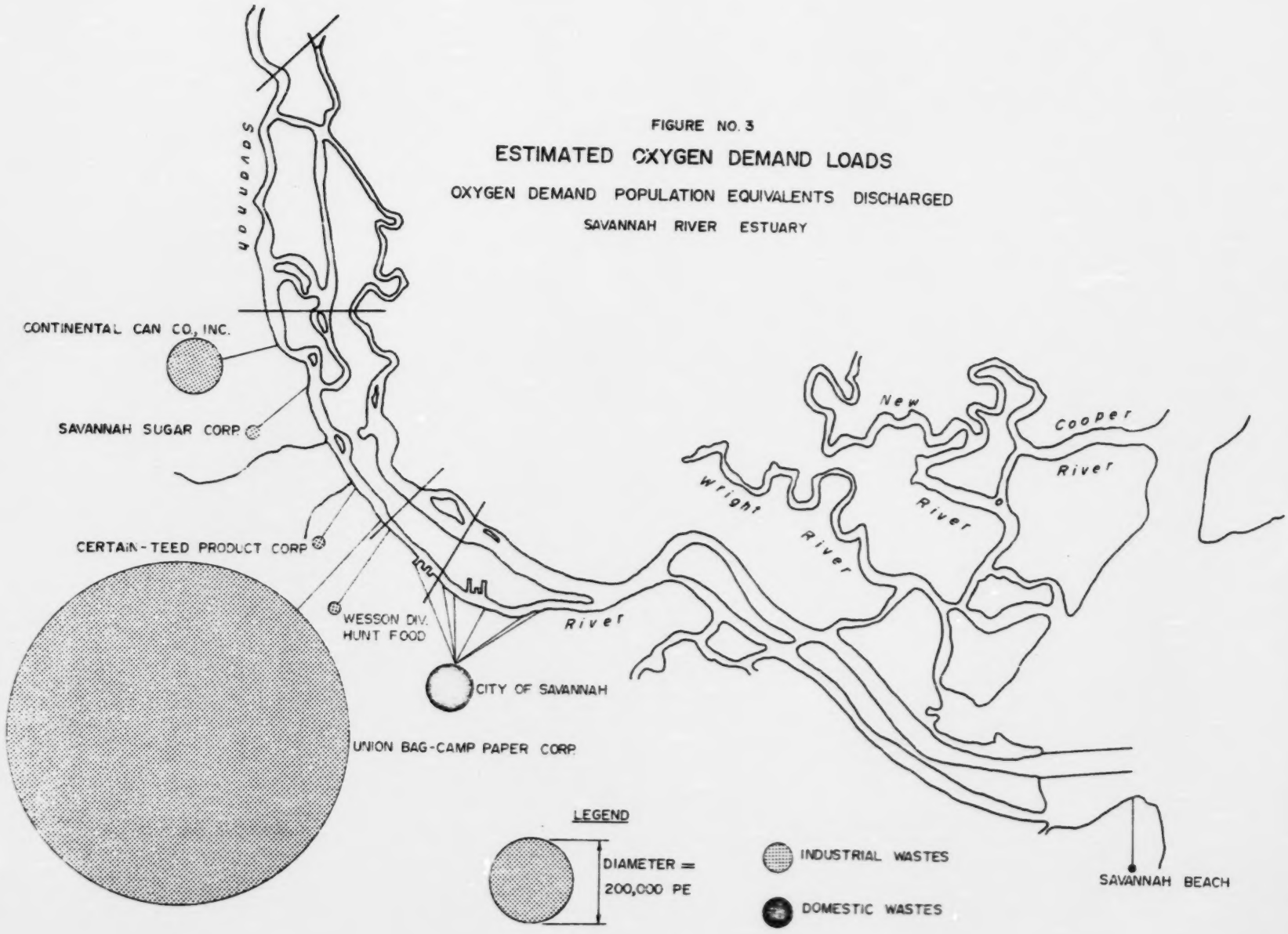
Almost 70 percent of the total load was discharged by Union Bag-Camp, approximately 11 percent of the total was discharged by the Continental Can Company, and about 9 percent was in the form of untreated raw sewage from the city of Savannah. Smaller loads, ranging from about 1.5 to 2.5 percent each, were discharged by the

FIGURE NO. 3

ESTIMATED OXYGEN DEMAND LOADS

OXYGEN DEMAND POPULATION EQUIVALENTS DISCHARGED

SAVANNAH RIVER ESTUARY



Savannah Sugar Refining Corporation, Certain-Teed Products Corporation, and the Savannah Beach primary sewage treatment plant. Industries and municipal jurisdictions discharging less than 1 percent of the total load each are tabulated in the preceding tables, but are not shown on this figure.

ACID WASTES

The American Cyanamid Company titanium dioxide plant, located at R.M. S-10.5, discharges an estimated 690,000 pounds of sulfuric acid into the river each day during ebb tide.

Analysis of the samples collected from the river during the August, 1963 survey indicates that additional acid wastes reached the river from above R.M. 16, north of the city of Savannah. The source of the waste which caused this increase in the acid content of the river has not been determined.

DISPERSION OF WASTES

The U. S. Army Waterways Experiment Station, in Vicksburg, Mississippi, ran tests on the Savannah Harbor Hydraulic Model to determine the dispersion characteristics of waste discharges from major sources of pollution in the Savannah Harbor, and to supplement the data collected during the on-site field study. Test results, including a description of the dye releases and the residual dye concentrations observed throughout the Model, were reported by the Waterways Experiment Station.* The test data were processed, analyzed, and interpreted by the Public Health Service.

Model Test Conditions

All tests were performed under normal conditions of mean tide, with a normal fresh water discharge of 7,000 cfs and an ocean salinity of 30 parts per thousand. Measured dye solutions were released into the Model at the location of known sources of pollution and residual dye concentrations were determined throughout the Model

*Pollution Studies, Savannah Harbor, Hydraulic Model Investigation, U. S. Army Engineer Waterways Experiment Station, Corps of Engineers, Vicksburg, Miss., Miscellaneous Paper No. 2-633, March, 1964.

at periods of both high and low water slack during each of 80 successive tidal cycles. The dispersion patterns of the dye used in the Model to simulate pollution were confirmed by the results of dye studies in the Savannah Estuary during the November, 1962 preliminary survey. Actual mean daily fresh water discharges, measured by the USGS gage at Clyo, Georgia, averaged 7180 cfs during the November, 1962 preliminary survey and 9170 cfs during the August, 1963 survey.

Time of Travel and Dilution Ratios

The estimated minimum times of travel and dilution ratios, calculated from instantaneous dye releases, at high water slack and at low water slack, in the Model at the city of Savannah location are summarized in the following table:

	Dye Release at High Water Slack	Dye Release at Low Water Slack
Minimum time to reach:		
Ocean at jetties	30 hours	72 hours
Mouth of Wright River	30 hours	72 hours
Station 12-9 Wright River	60 hours	96 hours
Mouth of New River	30 hours	72 hours
Station 10-10 New River	60 hours	96 hours
Dilution* ratio in:		
Ocean at jetties	4.6: 1	8.3: 1
Mouth of Wright River	23 : 1	40 : 1
Station 12-9 Wright River	29 : 1	48 : 1
Mouth of New River	32 : 1	58 : 1

*Dilution from the maximum concentration in the river near the outfall. (Stations shown on Fig. C.)

Dye Dispersion and Path of Travel

Dyes Released at the City of Savannah Location

Dyes released into the Model in the vicinity of the city of Savannah, simulating sewage and industrial waste discharges, undulated up and down the channel in response to flood and ebb currents, with a generalized net downstream movement. Approximately 70 percent travelled down the North Channel, and 30 percent down the South Channel. Of this total, approximately 5 percent entered the Wilmington River, 3 percent reached Savannah Beach, 1 percent entered the Wright River, and 1 percent entered the New River. Fields Cut, rather than the Ocean, was the predominant path of dye flow into the Wright and the New rivers. An extremely small amount of dye reached Calibogue Sound. About 90 percent of the dye remained in the predominantly South Carolina interstate waters between Savannah and Calibogue Sound, and gradually mixed into the Ocean.

Dyes Released at the Savannah Beach Location

About 10 percent of the dye released from the Savannah Beach sewage treatment plant outfall sewer location remained near Savannah Beach. Tidal currents carried somewhat less than 5 percent up the North Channel as far as Fields Cut. About 1 percent entered the Wright River, 1 percent entered the New River, and another 1 percent or less entered Calibogue Sound. Approximately 80 percent of the dye remained in the predominantly South Carolina interstate waters between Savannah Beach and Calibogue Sound, and gradually mixed into the Ocean.

Probable Influence of the Channel Improvement Plan Proposed by the U. S. Army Corps of Engineers

During one set of tests, the physical features of the Model were changed to simulate the proposed 38 ft. deep x 500 ft. wide channel in Front River and the sediment basin in Back River as proposed by the U. S. Army Engineers. Comparison of the dye data for the existing and proposed channel condition shows that, while there is some generalized movement of the dye downstream, there is no significant difference in the circulation of the dye outside of the North Channel. The dye data indicate that the proposed channel improvement plan will not significantly alter the effects of pollution on the tidal waters.

EFFECTS OF POLLUTION ON WATER QUALITY AND USE

Excessive bacterial pollution of a stream or estuary presents a health hazard to those who come in contact with the water, or consume raw shellfish harvested from polluted waters. Excessive oxygen demand reduces the dissolved oxygen of the water, which results in reduction or destruction of fish and desirable aquatic life.

During the August, 1963 field study, total coliform, fecal coliform, dissolved oxygen (D.O.), pH, and temperature data were collected at 2-hour intervals throughout a complete 12-hour tidal cycle at the sampling stations shown on Fig. 1. Three sampling runs of this type were made at most stations. Bacteriological samples were collected near the surface in the center channel. Separate dissolved oxygen, temperature and pH samples were collected near the top, mid-depth, and bottom of the center channel of the Savannah River and North Channel at approximately 5, 15, and 28 ft. depths. D.O. samples were not collected from the adjacent Wright, New or Cooper rivers.

The data collected during the study to measure the effects of pollution are summarized in the Appendix. Table A is a list of sampling stations. Tables B, C and D include summaries of the total

coliform and fecal coliform data and the calculated proportional effect of sewage from Savannah Beach and the city of Savannah. The D.O. summary is shown in Table E, and Tables F and G contain summaries of temperature and pH determinations.

BACTERIAL POLLUTION

Municipal sewage contains enormous numbers of bacteria, among which there usually are pathogenic bacteria, derived from human excreta, that can cause gastrointestinal diseases such as typhoid fever, diarrhea, and dysentery. These pathogenic bacteria, present in densities too low to be detected by available laboratory methods, can cause illness in persons who swallow water containing them. Oysters and other shellfish accumulate bacteria, in addition to other material, in their bodies and shell liquors as they filter the surrounding water in the process of feeding and respiration. Shellfish in waters polluted by sewage discharges can also accumulate pathogenic bacteria and viruses, such as those producing infectious hepatitis and polio. Although the bacteria and viruses do not normally harm the oyster, they can cause illness in persons who consume raw oysters harvested from waters containing them. As the densities of pathogenic bacteria are reduced by sewage treatment, dilution or forces of natural purification, the hazards of contracting diseases are proportionately reduced.

Sewage also contains bacteria of the coliform group which typically occur in excreta, or feces, and can readily be detected even at low densities. These bacteria, harmless in themselves, are determined in stream studies involving sewage pollution as indicators of the probable presence of pathogenic bacteria. In the absence of adequate methods for detection of other pathogenic organisms, such as viruses, in rivers or estuaries, coliform bacteria also serve as indicators of the probable presence of these organisms.

For many years the laboratory method for determination of the coliform group has been a principal tool used by sanitary engineers in evaluating bacterial pollution of surface waters. The coliform group has been used by numerous State and interstate water pollution control agencies as a basis for water quality objectives for various water uses. Unfortunately, the coliform group includes several types of bacteria which may come from sources other than excreta, and coliform data sometimes have been challenged because of this. In the last few years a method for specific detection of fecal coliform bacteria only has been developed. Although the method has the decided advantage of specificity, it has not been in use long enough to serve as a basis for quantitative water quality objectives. Both methods of bacterial measurement were applied to all samples in this study.

The results of both determinations are expressed in terms of most probable numbers, or MPN, per 100 milliliters (ml) of water. One hundred ml is a little less than one-half cup. The coliform group usually is designated as total coliforms.

Neither Georgia nor South Carolina has adopted total coliform objectives of water quality for water contact sports, such as swimming and water skiing, or for general recreational use, such as boating and fishing, for the Savannah River Estuary.

Where such objectives have been adopted, the commonly used limit for water contact sports is 1,000 per 100 milliliters (ml) of water. This swimming water standard is used by South Carolina in other classified waters of the State.

Where total coliform objectives for general recreational use have been adopted, an arithmetic average of 5,000 MPN per 100 milliliters (ml) is the commonly used upper limit. It has been stated that the Savannah is a working river, and the U. S. Army Corps of Engineers alone reports that more than 100 persons in their organization work on the river. Exposure to the Savannah River waters, by work crews handling lines and equipment submersed in the waters, and travelling the rivers in small as well as large boats, is similar in many respects to the exposure for fishing and recreational boating, and the same total coliform water quality objective of 5,000 per 100 ml could logically apply.

Both states prohibit direct harvesting of shellfish for human consumption from waters polluted by sewage. The suitability of tidal waters for shellfish harvesting is based on the results of sanitary surveys and bacterial analysis of the waters. Waters subject to sewage pollution are closed to shellfishing by Georgia and South Carolina State Health Departments, where sanitary surveys indicate that sewage may reach the waters, or where the median total coliform

MPN value representative of the waters of the shellfish growing areas exceeds 70/100 ml. The Public Health Service Manual of Recommended Practice also states that 230 MPN/100 ml should not be exceeded in more than 10 percent of the samples from approved waters.

Savannah River - Main Channels

The average MPN values for both total and fecal coliform bacteria observed in the main channels of the Savannah River during the August, 1963 survey are shown on the bar chart in Figure 4.

Results on individual samples, collected at 2-hour intervals throughout the entire 12-hour tidal cycle, ranged above and below the illustrated averages in response to movement of the main pollutional mass up and down the channel, and to the varying quantities of dilution by fresh water entering the upper reaches during ebb tide and the ocean water entering the mouth during flood tide.

During ebb tide the mass of polluted water moves down stream with a minimum of ocean water dilution, and about the time of low water slack the coliform densities at stations below the sources of pollution regularly exceeded the average densities. Similarly, coliform densities at stations up stream from the sources of pollution reach cyclical highs about the time of high water slack after flood tide. The coliform density that was exceeded 10 percent of the time at each sampling station, rather than the absolute maximum observation, was selected to indicate the increased coliform densities that can recur during the critical period of each tidal cycle. The values

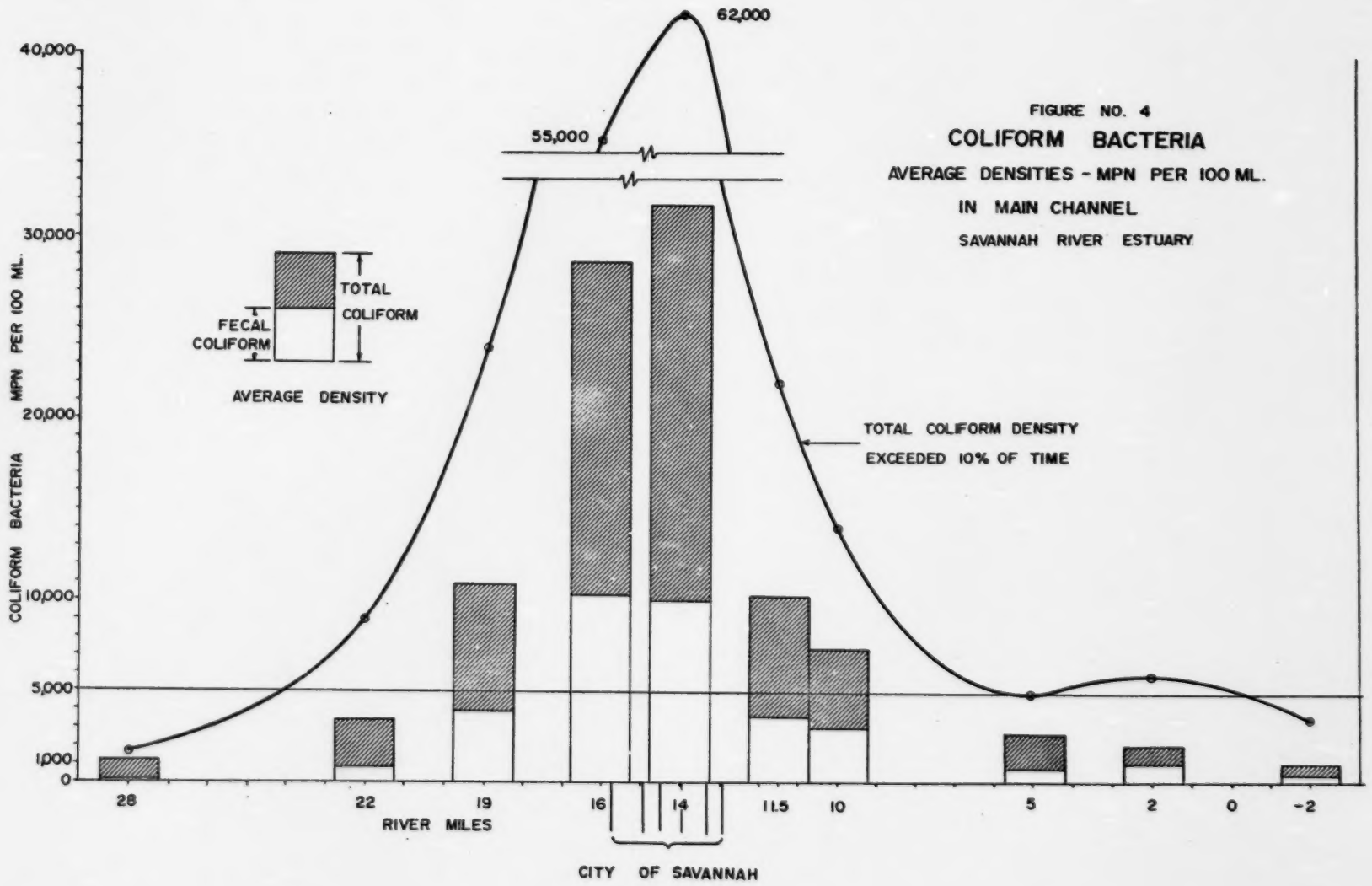


FIGURE NO. 4

COLIFORM BACTERIA

AVERAGE DENSITIES - MPN PER 100 ML.

IN MAIN CHANNEL

SAVANNAH RIVER ESTUARY

exceeded 10 percent of the time, shown as the solid line on Figure 4, exceed the average values by a ratio of about 2 to 1. The 5,000 MPN/100 ml line on Figure 4 permits comparison of the values found in the Savannah River with the total coliform water quality objective most commonly used for general aquatic recreation, exclusive of body contact sports.

At the uppermost station (R.M. 28), above known sources of pollution and the influence of tidal currents, the average coliform density of 1,200 was in the range considered acceptable for general recreation.

Total coliform densities averaged 3400 MPN/100 ml at the U. S. Highway 17 bridge (R.M. 22) above Port Wentworth. This station is within the upstream limits of tidal influence and 10 percent of the total coliform densities exceeded 9,000 MPN/100 ml.

The average coliform densities exceeded the 5,000 MPN/100 ml objective in the 9-mile reach from R.M. 19, located above the city of Savannah to R.M. 10, where the main channel branches off to South and North channels.

The average total coliform density rose to a peak of 31,800 MPN/100 ml at R.M. 14 in the Georgia waters at the city of Savannah. At this station, the total coliform densities exceeded 62,000 during 10 percent of the time, and never fell below 9,000. That this increase in bacterial densities is caused primarily by bacteria derived from excreta is confirmed both by the fecal coliform densities, which averaged 10,000 and exceeded 24,000 MPN/100 ml more than 10

percent of the time, and by the known discharge of untreated raw sewage into the river above and below this sampling station.

In the interstate waters near the mouth of Back River, (S-11.5-0.5), the total coliform bacterial densities averaged 10,300 and exceeded 22,000 MPN/100 ml 10 percent of the time. Fecal coliforms averaged 3,500 MPN/100 ml.

At R.M. S-10 about one-half mile above the Georgia-South Carolina State line, where the Savannah River divides to form the North and South channel, the total coliform densities averaged 7,200 and exceeded 14,000 10 percent of the time. Fecal coliforms averaged 2,900 MPN/100 ml.

The average coliform densities at sampling stations in the interstate and intrastate reaches of the North Channel from below River Mile S-10.0 to the mouth were reduced below the 5,000 MPN/100 ml standard for general recreation. The 10 percent values, however, equalled or exceeded the objective in 8 of the 10 miles. Coliform bacteria in these waters contributed to pollution of the adjoining Wright and New rivers in South Carolina, where total coliform densities exceeded the allowable limits for shellfishing.

The 70 MPN/100 ml median and 230 MPN/100 ml decile total coliform objectives for shellfish waters were exceeded throughout the entire reach of the Savannah River included in this study.

Wright, New and Cooper Rivers

Coliform densities continued to decrease in waters more remote from the sources of pollution, but the coliform densities of certain waters of the Wright and New rivers in South Carolina exceeded the 70 MPN/100 ml limit for water used for shellfish harvesting.

The median total coliform and fecal coliform densities are illustrated in the bar charts of Figure 5, and a line representing the shellfishing total coliform objective of 70 MPN/100 ml is shown near the bottom of the chart. The median density, which is the density that is equalled or exceeded by 50 percent of the samples, was determined by plotting the coliform data on logarithmic probability paper.

Where Fields Cut, which is connected directly to the North Channel of the Savannah River, enters the Wright River the median total coliform concentration reached 1,800, and the fecal coliform concentration reached 840 MPN/100 ml.

Median total coliform bacterial concentrations at the other Wright River stations ranged from 175 at the upstream station to 380 MPN/100 ml at the mouth. Median fecal coliform densities in the same reach of the Wright River ranged from 66 to 170 MPN/100 ml. The total coliform densities at these stations exceeded the 230 MPN/100 ml limit from 42 to 73 percent of the time.

A median total coliform density of 65 was observed at the uppermost station in the New River, but the medians in three of the four stations ranged from 80 upstream to 120 MPN/100 ml at the mouth.

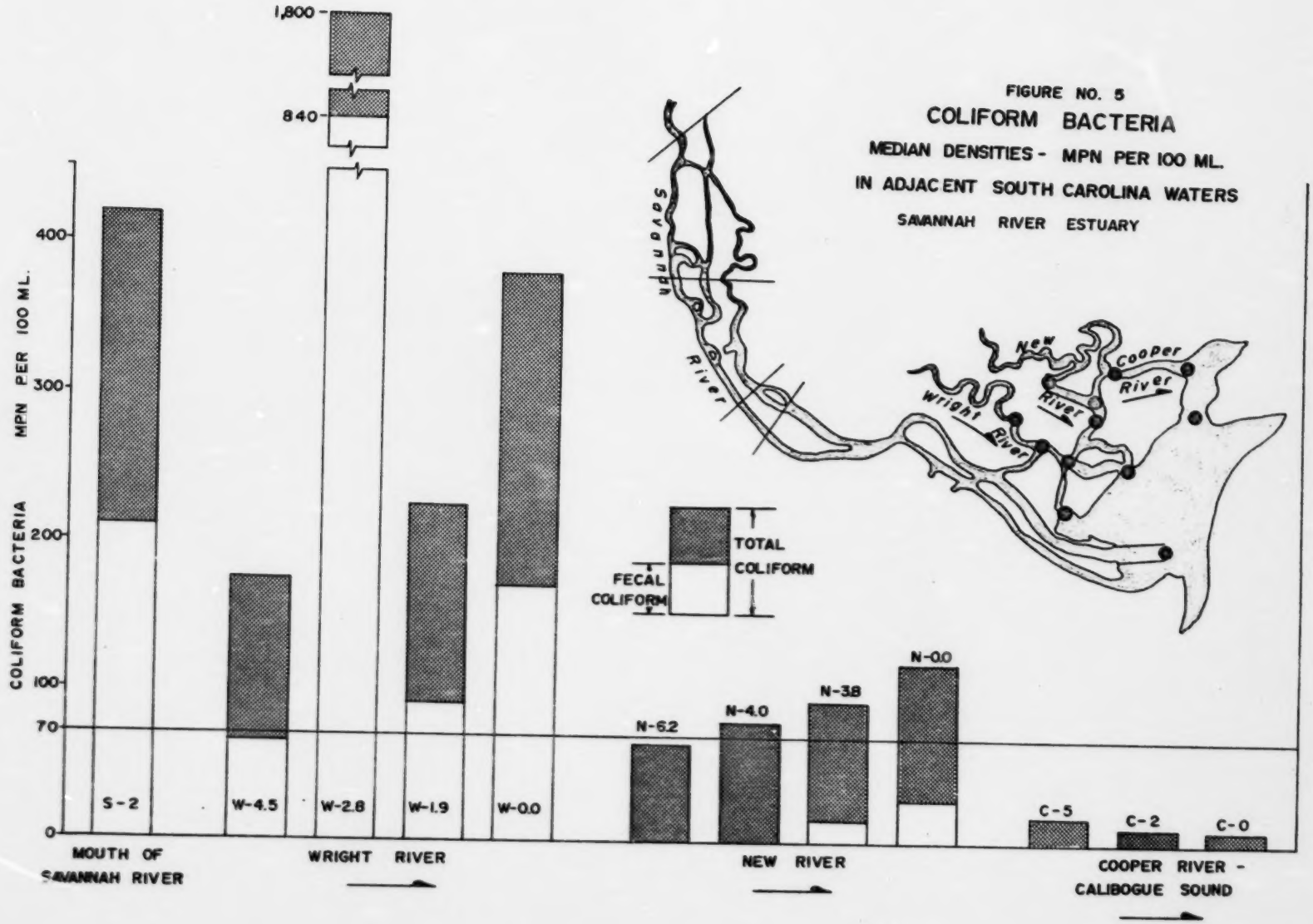
FIGURE NO. 5

COLIFORM BACTERIA

MEDIAN DENSITIES - MPN PER 100 ML.

IN ADJACENT SOUTH CAROLINA WATERS

SAVANNAH RIVER ESTUARY



The median fecal coliform density for three of the four stations was less than 20, and a median of 29 MPN/100 ml was observed at the mouth. The total coliform densities at all New River stations exceeded the 230 MPN/100 ml limit from 14 to 28 percent of the time.

Throughout the August, 1963 survey, the total coliform densities in Calibogue Sound and the Cooper River remained consistently below the 70 MPN/100 ml standard.

Proportionate Effects of Sewage Discharges from Savannah Beach and the City of Savannah

As indicated previously, raw sewage from the city of Savannah, entering the Front River channel of the Savannah River, accounted for approximately 82 percent of the total bacterial discharge to the river. This, combined with 10 percent of the total discharged near the mouth of the South Channel from the Savannah Beach sewage treatment plant, represents about 92 percent of the total bacterial load discharged to the estuary. During studies made on the U. S. Corps of Engineers Savannah River Harbor Model, dyes were discharged into the river at the location of the city of Savannah sewers and the Savannah Beach sewage treatment plant outfall. The estimated proportionate effect of bacterial pollution from these two sources alone was calculated from the dye observations at sampling stations throughout the estuary. A summary of the Model test observations and calculations, which were based on time of travel, age of pollution, effect of dilution, and coliform die-off rates in brackish water, are illustrated on Figure 6.

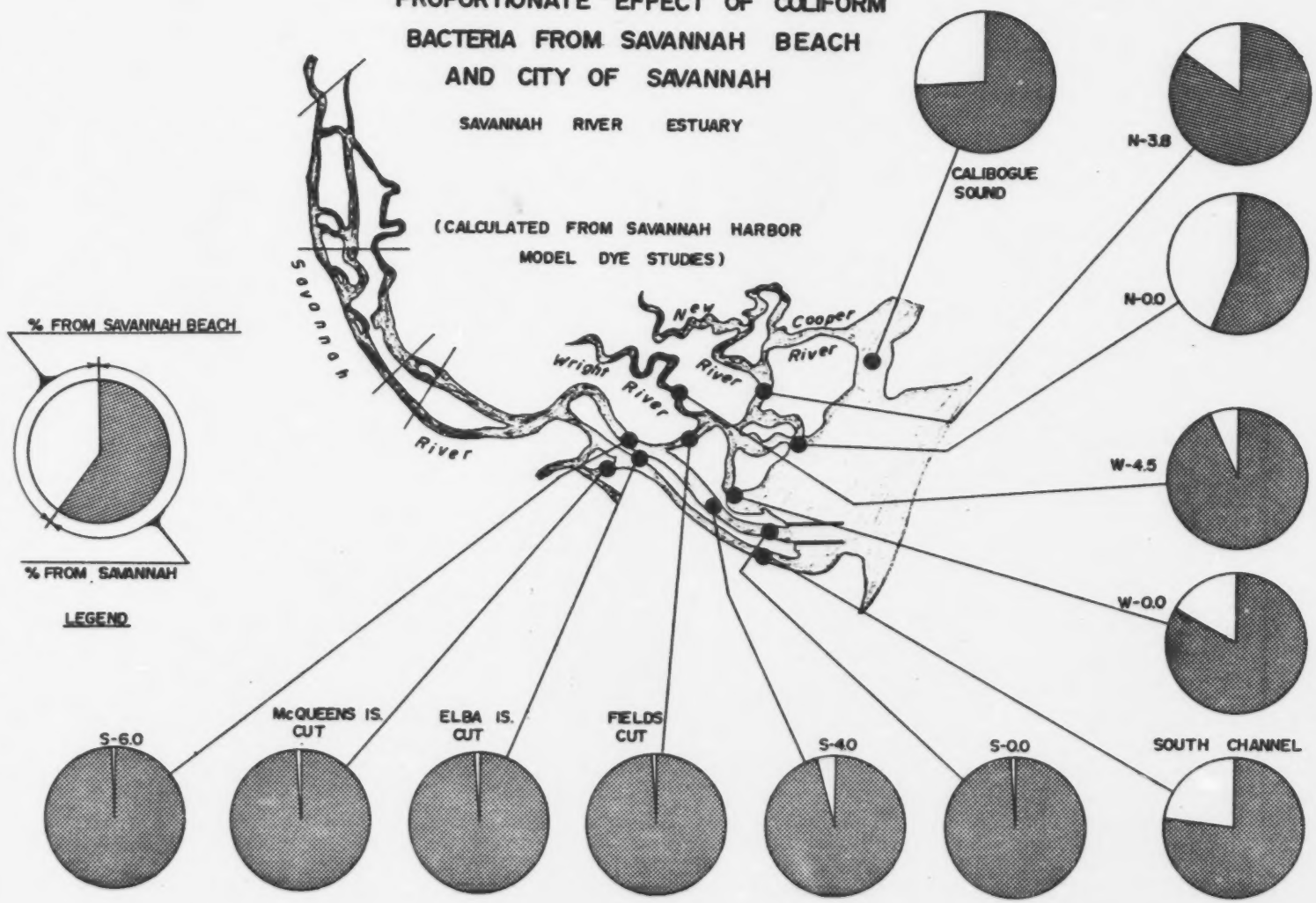
Separate tests were not run on simulated discharges from all

FIGURE NO. 6

PROPORTIONATE EFFECT OF COLIFORM BACTERIA FROM SAVANNAH BEACH AND CITY OF SAVANNAH

SAVANNAH RIVER ESTUARY

(CALCULATED FROM SAVANNAH HARBOR MODEL DYE STUDIES)



sources of pollution. The smaller jurisdictions discharging the remaining 8 percent of the total bacterial load included the 3 percent from Port Wentworth Corporation and 4 percent from Garden City. The sewage from these jurisdictions generally follows the path of the city of Savannah sewage and their respective responsibilities for pollution of the waters are in proportion to their relative discharges.

The circles in Figure 6 illustrate the estimated percent of the bacterial pollution from Savannah Beach and the city of Savannah at various points in the estuary that is attributable to each of these two sources of sewage pollution. The shaded portion shows the percent attributable to the city of Savannah.

Approximately 99 percent, or almost all of the bacteria from these two sources in the main channel and at Fields Cut came from the city of Savannah. Similarly, 94 percent of the residual 4.5 miles up the Wright River, and 85 percent at the mouth of the Wright River are also attributable to the city of Savannah discharges. This percentage is reduced near the mouth of the New River, where slightly more than one-half, or approximately 57 percent, is attributable to the city of Savannah, and approximately 43 percent is attributable to Savannah Beach. The results of this study indicate that the pollutional effects of sewage from the city of Savannah predominate, but that the unchlorinated effluent from the Savannah Beach sewage plant contributes significantly to bacterial pollution of limited areas of the South Carolina waters.

Areas Closed to Shellfishing

The areas closed to shellfishing are illustrated on Figure 7. The shaded areas show the main river channels, and that portion of the adjacent tidal waters that have been closed to shellfish harvesting by the Georgia and South Carolina Health Departments. These waters were closed because of the potential health hazard to persons who might consume oysters which had accumulated bacteria from the raw and inadequately treated domestic sewage. Approximately 11,000 acres of coastal waters in the Savannah area are closed to shellfishing.

The South Carolina State Board of Health has condemned the areas described as "half of the Savannah River along South Carolina shores, Mud Creek, Wright River, and unmarked creek to Tybee Roads, New River to above Ram's Horn Creek" for the taking of shellfish.

Bacterial pollution discharged to the Savannah River Estuary in Georgia causes a health hazard to persons who come in contact with the river, or who may consume oysters harvested from the estuary, in South Carolina as well as in Georgia.

OXYGEN DEMAND AND DISSOLVED OXYGEN

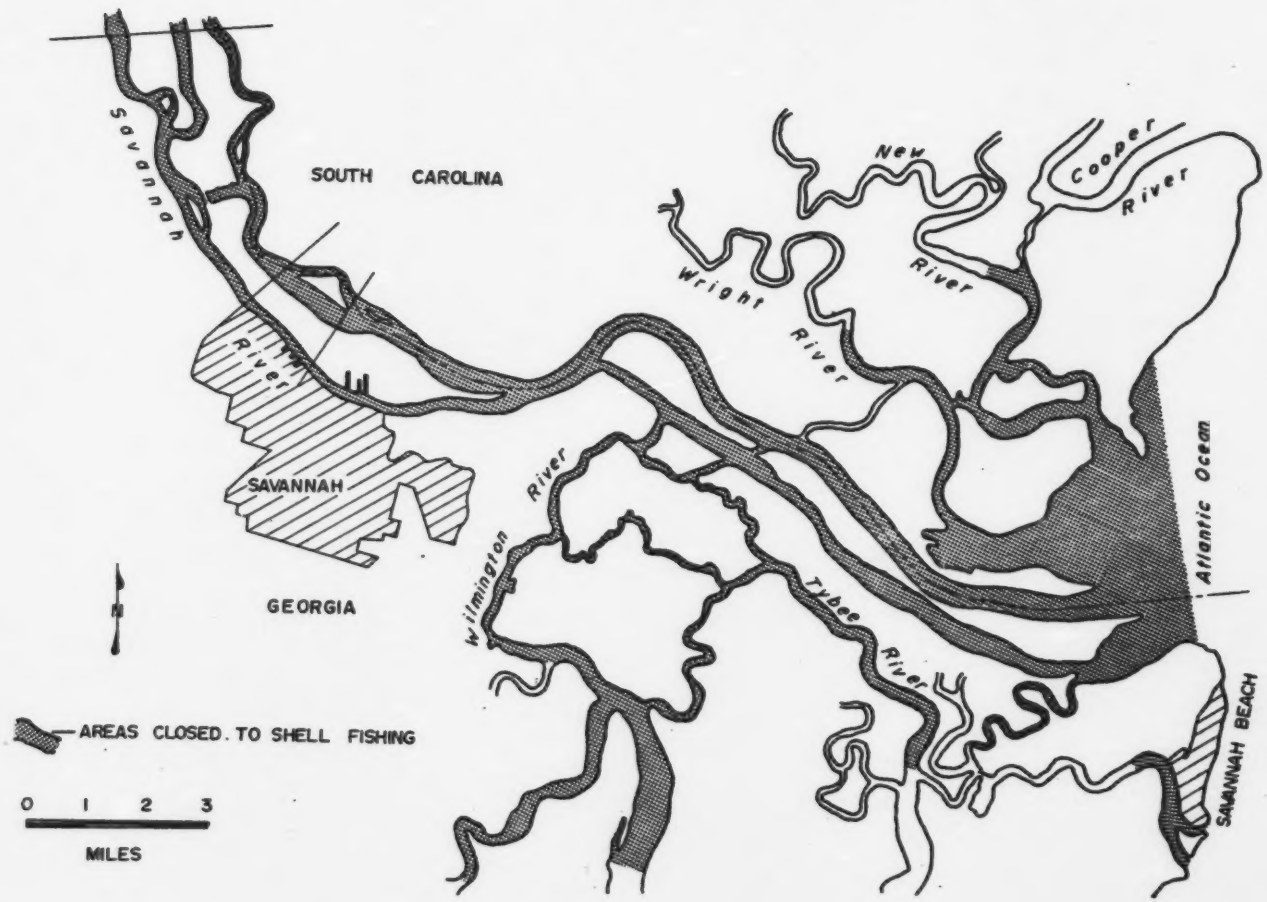
Both sewage and many industrial wastes contain organic material that decomposes and exerts an oxygen demand in the receiving waters. In the process of decomposition, oxygen derived from the atmosphere and dissolved in the water is used, and the normal content of dissolved oxygen (DO) is reduced. If the DO is reduced below an adequate level, the fish population and aquatic life on which the fish feed are reduced. Estuaries are the nurseries of many important commercial fish and

FIGURE NO. 7

AREAS CLOSED TO SHELL FISHING

GEORGIA - SOUTH CAROLINA

SAVANNAH RIVER ESTUARY



shellfish. Anadromous fish, such as the American shad, pass up through estuaries to gain access to the fresh waters to spawn, and the juvenile fish return through these areas during their annual migration back to the ocean. Inadequate dissolved oxygen in a tidal river during the spring spawning run, or in late summer or early fall when the young are migrating to the ocean, can reduce or eliminate migration of anadromous fish through such areas.

Most water pollution control agencies have adopted an average of 5 mg/l as the minimum DO that is adequate to maintain the maximum potential sport fish population. Neither Georgia nor South Carolina has adopted minimum DO standards for waters in the Savannah River Estuary. In other waters of the State that have been classified, South Carolina classification standards stipulate that the dissolved oxygen in class SC waters, used for crabbing and non-commercial fishing, shall not be less than 4 ppm.

As shown on Figure 8, during the three-week August, 1963 stream survey, the average dissolved oxygen concentrations in the river were reduced from 6.5 mg/l at R.M. S-28, above the known sources of pollution, to 1.8 mg/l at R.M. S-10.0. In the interstate waters near the mouth of Back River (S-11.5-0.5) and at S-10.0 in the Georgia waters, one-half mile above the point where North Channel forms the interstate boundary, the minimum DOs near the surface, at mid-depth, and near the bottom, were all below 1.0 mg/l.

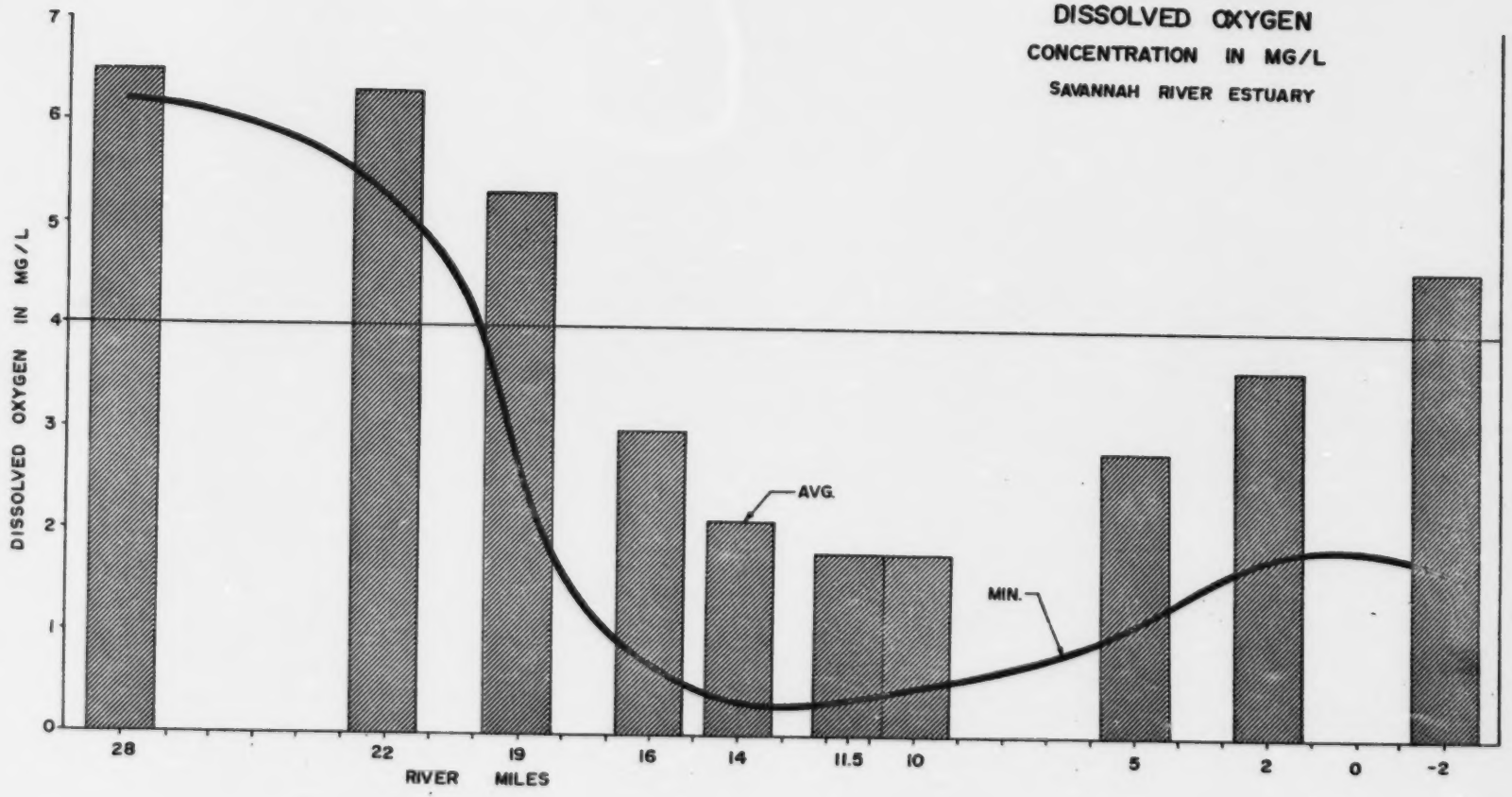
At R.M. S-5.0, in the interstate waters of the North Channel near Field's Cut, the average of 71 DO samples amounted to 2.8 mg/l

FIGURE NO. 8

DISSOLVED OXYGEN

CONCENTRATION IN MG/L

SAVANNAH RIVER ESTUARY



and the minimum values ranged from 1.1 near the surface to 1.6 near the bottom.

Dissolved oxygen concentrations increased at succeeding downstream stations, but even at the mouth (S--2.0), where the tidal flood flows sweep in from the ocean, the DO averaged only 4.6 and minimum values of 1.7, 2.7, and 3.2 were observed near the surface, at mid-depth, and near the bottom.

On Figure 9, the percent of samples containing less than 4.0 mg/l of DO is shown by the shaded area in each circle. The DO in the river was frequently less than 4.0 mg/l at all sampling stations in the 21 mile reach from S-19, off shore from the Chatham County industrial complex, down to the mouth. All samples collected from the interstate waters at the mouth of Back River and from the Georgia waters at S-10 contained less than 4.0 mg/l of DO.

Three-quarters of the samples collected from the interstate waters at S-5 near Fields Cut contained less than 4.0 mg/l. At this station, 60 percent of the samples contained less than 3.0, and 21 percent contained less than 2.0 mg/l of DO.

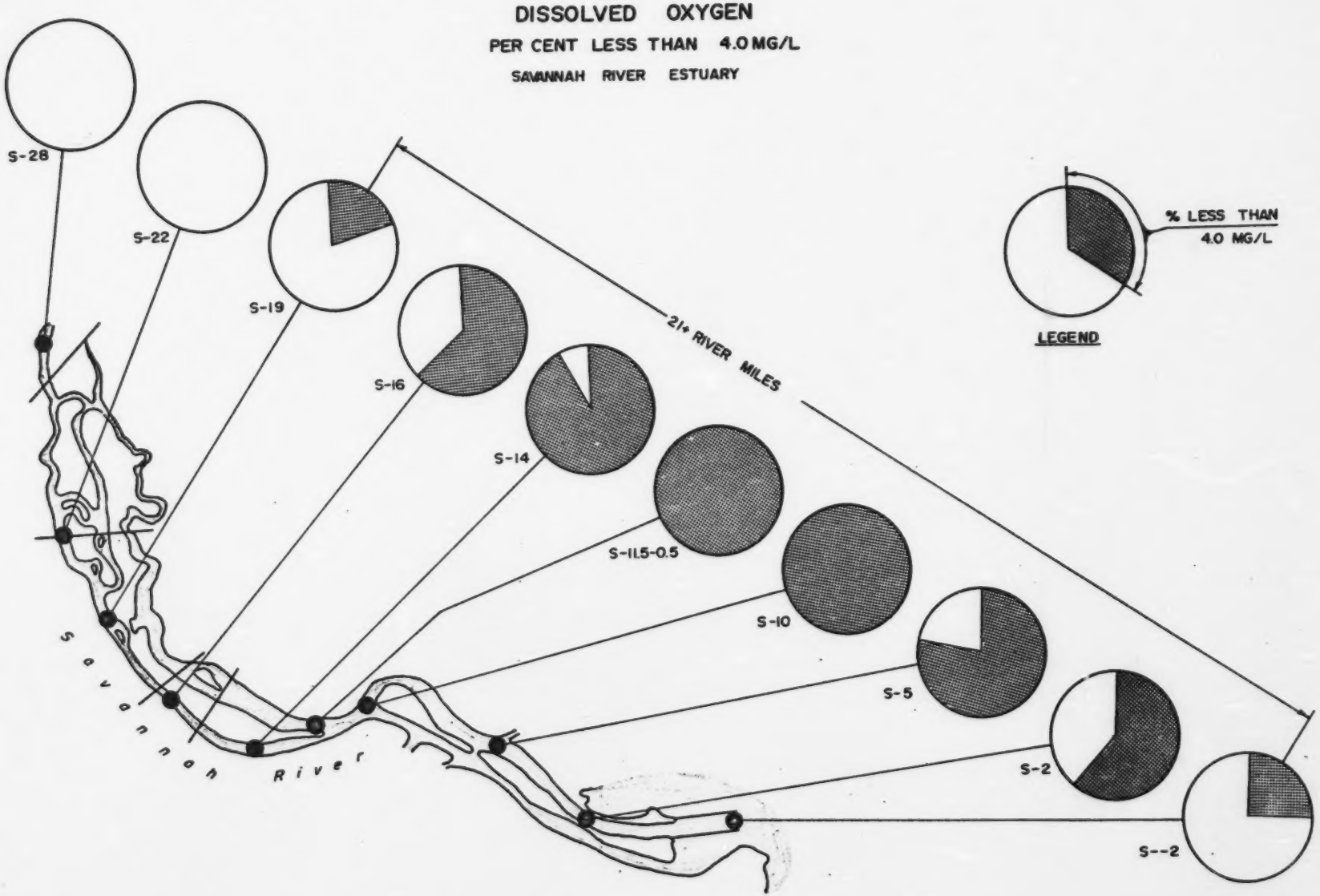
Oxygen-demanding pollution entering the river in Georgia reduced the dissolved oxygen levels of waters in Georgia and South Carolina below the generally accepted water quality objectives for the propagation of fish and other desirable forms of aquatic life.

FIGURE NO. 9

DISSOLVED OXYGEN

PER CENT LESS THAN 4.0 MG/L

SAVANNAH RIVER ESTUARY



OIL POLLUTION

Accidental oil spills have occurred occasionally during oil transfer operations at marine terminals in the harbor. Because of the attendant fire hazard, oil companies report such spills promptly, and the U.S. Coast Guard proceeds to the scene immediately and injects Gamelen Solvent D into the water to emulsify the oil and eliminate the oil slick. Those responsible for an unreported oil spill are subject to a $2,000 fine.

RADIOACTIVITY

The E. I. DuPont deNemours Company operates an atomic energy installation under contract with the U. S. Atomic Energy Commission in an area adjoining the Savannah River some 25 river miles below Augusta, Georgia, and about 150 river miles above the study area. The discharge of radioactive wastes to the river is under careful control and surveillance. Although this location is about 150 river miles above the limit of the study area, the possibility of radioactive pollution was investigated because of the persistence of some radio-isotopes.

The Public Health Service maintains national Water Pollution Surveillance System stations on the Savannah River near Augusta, Georgia, above the atomic energy installation, and at Port Wentworth at R.M. 22, which is below the atomic energy installation and within the study area. Comparison of data on gross radioactivity at these two stations has shown that the atomic energy installation is not contributing significant radioactivity to the Savannah River.

APPENDIX

Table No. A

SAMPLING AND REFERENCE POINT LOCATIONS

August, 1963 Survey
Savannah River Estuary

River Mile	Aug. 1963 Field Station	Description	Dye Test Stations	
			Test Nos. 1,2,3,4	Test No. 5
Savannah River (Main Channel)				
28.0	11	Upper Limit Aug. 1963 Survey		
27.0		Atlantic Coastline R.R. Bridge		
23.0			27	
22.0	9	Atlantic Coastal Hwy. Bridge(US-17)		
21.6		Upper Industrial Limit (Dye Release)		
20.9		Continental Can Co.		
20.7		Port Wentworth Sewer Outfall		
20.4		Port Wentworth Sewer Outfall		
20.0		Port Wentworth Sewer Outfall		
20.0			18	
19.9		Atlantic Creosoting Co.		
19.8		Savannah Sugar Corp.		
19.4		Amer. Bitumuls & Asphalt Co.		
19.4		Southern Nitrogen Co., Inc.		
19.0	8			
18.5		Pipemakers Canal		
18.0			19	
17.7		Southland Oil Corp.		
17.4		Hercules Powder Co.		
17.4		The Ruberoid Co.		
17.4		Amer. Agricultural Chem.		

Table No. A
Cont.

SAMPLING AND REFERENCE POINT LOCATIONS

August, 1963 Survey
Savannah River Estuary

River Mile	Aug. 1963 Field Station	Description	Dye Test Stations	
			Test Nos. 1,2,3,4	Test No. 5
Savannah River (Main Channel) Cont.				
17.4		Dundee Canal		
17.3		Allied Chem. Corp. - Gen. Chem. Div.		
17.3		Certain-Teed Product Corp.		
17.1		American Oil Co.		
17.0		Johns-Manville Products Corp.		
16.7		Dixie Asphalt		
16.6		Union Bag-Camp Paper Corp.(Dye Release		
16.5		Seaboard Airline R. R. Bridge		
16.2		Wesson Div. - Hunt Food & Ind. Inc.		
16.2		Virginia-Carolina Chem. Corp.		
16.1		Southern Cotton Oil Co.		
16.0	7		20	
15.7		Colonial Oil Industries Terminal		
15.7		Savannah City Sewer Outfall		
15.1		Talmadge Memorial Bridge		
15.0		Meddin Packing Co.		
15.0		Savannah & Ogeechee Canal		
14.9		Savannah City Sewer Outfall		
14.6		Savannah City Sewer Outfall		
14.6		Gulf Oil Corp.		
14.5		So. Fertilizer & Chem. Co.		
14.5		Bull St. - City of Savannah (Dye Release)		

Table No. A
Cont.

SAMPLING AND REFERENCE POINT LOCATIONS

August, 1963 Survey
Savannah River Estuary

River Mile	Aug. 1963 Field Station	Description	Dye Test Stations Test Nos. 1,2,3,4	Test No. 5
Savannah River (Main Channel) Cont.				
14.0	6		21	
13.9		Savannah City Sewer Outfall		
13.3		Savannah City Sewer Outfall		
13.1			128	
13.0		Southern States Phosphate & Fertilizer Co.		
12.9		Savannah City Sewer Outfall		
11.7		Atlantic Refining Co.		
11.6		Pure Oil Co.		
11.5		Standard Oil Co.		
11.5-0.5	5	Back River	15	
11.0			22	
10.5		American Cyanamid		
10.2		Lower Industrial Limit (Dye Release)		
10.0	4	North & South Channel Branch Off		
Savannah River (North Channel)				
8.0			23	
7.4			157	
6.0			24	16
5.0	3	Vicinity of Fields Cut		
4.0			25	14
2.0	2			

Table No. A
Cont.

SAMPLING AND REFERENCE POINT LOCATIONS

August, 1963 Survey
Savannah River Estuary

River Mile	Aug. 1963 Field Station	Description	Dye Test Stations Test Nos. 1,2,3,4	Dye Test Stations Test No. 5
Savannah River (North Channel) Cont.				
0.0		Fort Pulaski Natl. Monument	26	7
-2.0	1			
-5.0		Savannah River, Main Channel	28	
Savannah River (South Channel)				
9.5		South Channel	6	
1.0		South Channel - Ft. Pulaski	5	6
Savannah River (Middle River)				
		Middle River Opposite RM 21.6	17	
Wright River				
4.5	15	Wright River	9	12
2.8	14	Wright River		
0.0	12	Wright River, Mouth	12	8
	13	Walls Cut		19
		Fields Cut	8	13
New River				
6.2	19	New River		20
4.0	18	New River		
3.8	17	New River	10	10
0.0	16	New River, Mouth	11	9

Table No. A
Cont.

SAMPLING AND REFERENCE POINT LOCATIONS

August, 1963 Survey
Savannah River Estuary

River Mile	Aug. 1963 Field Station	Description	Dye Test Stations	
			Test Nos. 1,2,3,4	Test No. 5
Cooper River - Calibogue Sound				
5.0	22	Cooper River		
3.8		Cooper River		21
2.0	21	Cooper River, Mouth		
1.0		Calibogue Sound	13	11
0.0	20	Calibogue Sound		
Wilmington River				
5.0		Wilmington River, Hwy. 80 Crossing	2	
1.8		Wilmington River, Couston Bluff	1	
0.3		Wilmington River	3	
Other Stations				
		Savannah Beach, 600 yds. East of T.P.		4
		Savannah Beach, Base of 2nd St.	14	3
		Savannah Beach, Public Boat Landing, 16th St.		2
		Tybee Creek, Mouth		1
		Lazaretto Creek, Mouth		5
		McQueens Island Cut	4	17
		Elba Island Cut	7	15
		Tybee River	31	18

TOTAL COLIFORM BACTERIA (MPN/100 ml)

Table No. B

August, 1963 Survey
Savannah River Estuary

Station Location River Mile	Lab. No.	No. of Samples	Total Coliform Densities (MPN/100 ml) Median Value	Values Exceeded 10% of Time	Values Exceeded 90% of Time	Arith. Average	Max.	Min.	% of Time Various Water Use Objectives Were Exceeded 70	230	1,000	5,000
Savannah River												
S-28	11	9	1,100	1,720	330	1,220	1,720	330	100	100	60	0
S-22	9	11	2,400	9,000	600	3,430	9,200	790	100	100	80	24
S-19	8	11	7,000	> 24,000	2,400	10,850	> 24,000	2,400	100	100	100	58
S-16	7	26	21,000	55,000	9,000	28,600	92,000	5,400	100	100	100	100
S-14	6	26	24,000	62,000	9,000	31,800	160,000	9,200	100	100	100	100
S-11.5-0.5	(5)	28	8,000	22,000	3,000	10,300	34,800	2,200	100	100	100	73
S-10	4	27[1]	5,500	14,000	2,200	7,250	> 24,000	1,720	100	100	100	54
S-5	3	29[2]	2,200	5,000	270	2,650	9,200	230	100	100	75	10
S-2	2	31	1,000	6,000	150	2,080	9,200	200	100	85	50	12
S--2	1	30	420	3,500	50	1,050	5,420	40	86	64	30	7
Wright River												
W-4.5	15	28	175	990	32	350	2,100	20	76	42	10	0
W-2.8	14	28	1,800	6,100	52	2,200	9,200	40	86	71	57	18
W-1.9	13	29	225	960	50	460	1,720	80	85	49	9	0
W-0.0	12	29	380	1,090	130	500	1,700	< 200	100	73	12	0

1. Not including questionable > 240,000 MPN/100 ml 1:30 PM 8/13/63.
2. Not including questionable 24,000 MPN/100 ml 4:45 PM 8/21/63.

TOTAL COLIFORM BACTERIA (MPN/100 ml)

Table No. B cont.

August, 1963 Survey
Savannah River Estuary

Station Location River Mile	Lab. No.	No. of Samples	Total Coliform Densities (MPN/100 ml) Median Value	Values Exceeded 10% of Time	Values Exceeded 90% of Time	Arith. Average	Max.	Min.	% of Time Various Water Use Objectives Were Exceeded 70	230	1,000	5,000
New River												
N-6.2	19	28	65	290	5	115	490	20	48	14	0	0
N-4.0	18	29	80	370	19	130	490	< 20	56	19	0	0
N-3.8	17	30	94	300	30	130	490	20	62	16	0	0
N-0.0	16	27	120	490	30	220	790	20	69	28	0	0
Cooper River - Calibogue Sound												
C-5	22	23	17	81	< 5	36	170	< 20	12	2	0	0
C-2	21	23	11	410	< 5	62	230	< 20	26	14	0	0
C-0	20	22	10	110	< 5	44	230	< 20	15	5	0	0

FECAL COLIFORM BACTERIA (MPN/100 ml)

Table No. C

August, 1963 Survey
Savannah River Estuary

Station Location River Mile	Lab. No.	No. of Samples	Fecal Coliform Densities (MPN/100 ml) Median Value	Values Exceeded 10% of Time	Values Exceeded 90% of Time	Arith. Average	Max.	Min.	Ratio - Fecal/Total Coliforms Median Value	Arith. Average	10%	90%
Savannah River												
S-28	11	9	130	470	40	180	490	20	0.12	0.15	0.12	0.27
S-22	9	11	300	4,500	130	860	3,480	130	0.12	0.25	0.22	0.50
S-19	8	11	2,300	13,000	800	3,900	9,200	790	0.33	0.36	0.33	-
S-16	7	26	6,100	26,000	2,200	10,350	54,200	1,720	0.29	0.36	0.24	0.47
S-14	6	26	9,000	24,000	3,500	10,000	34,800	2,210	0.38	0.31	0.39	0.39
S-11.5-0.5	(5)	28	3,000	8,700	860	3,530	10,900	500	0.38	0.34	0.29	0.40
S-10	4	27[1]	2,300	5,000	500	2,930	9,200	330	0.42	0.40	0.23	0.36
S-5	3	29[2]	500	1,700	150	780	2,300	130	0.23	0.29	0.56	0.34
S-2	2	31	400	2,700	150	1,020	5,420	110	0.40	0.49	1.00	0.45
S--2	1	30	210	1,200	30	420	3,300	< 20	0.50	0.40	0.60	0.34
Wright River												
W-4.5	15	28	66	360	< 20	130	790	< 20	0.38	0.37	-	0.35
W-2.8	14	28	840	3,100	< 20	1,050	3,480	< 20	0.47	0.48	-	0.51
W-1.9	13	29	92	480	18	180	800	< 20	0.41	0.39	0.36	0.50
W-0.0	12	29	170	490	58	220	700	50	0.45	0.44	0.45	0.45

1. Not including questionable > 240,000 MPN/100 ml 1:30 PM 8/13/63.
2. Not including questionable 5,420 MPN/100 ml 4:45 PM 8/21/63.

FECAL COLIFORM BACTERIA (MPN/100 ml) Table No. C cont.

August, 1963 Survey
Savannah River Estuary

Station Location River Mile	Lab. No.	No. of Samples	Fecal Coliform Densities (MPN/100 ml) Median Value	Values 10% of Time	Exceeded 90% of Time	Arith. Average	Max.	Min.	Ratio - Fecal/Total Coliforms Median Value	Arith. Average	10%	90%
New River												
N-6.2	19	28	< 20	58	< 20	< 28	110	< 20	-	-	-	0.20
N-4.0	18	29	< 20	54	< 20	< 26	80	< 20	-	-	-	0.15
N-3.8	17	30	15	63	< 20	29	80	< 20	0.16	0.22	-	0.21
N-0.0	16	27	29	110	< 20	46	130	< 20	0.24	0.21	-	0.22
Cooper River - Calibogue Sound												
C-5	22	23	< 20	37	< 20	< 23	90	< 20	-	-	-	0.46
C-2	21	23	< 20	46	< 20	< 27	130	< 20	-	-	-	0.11
C-0	20	22	< 20	28	< 20	< 21	50	< 20	-	-	-	0.25

Table No. D

PROPORTIONATE EFFECT OF SIMULATED SEWAGE DISCHARGES FROM SAVANNAH BEACH AND THE CITY OF SAVANNAH

Calculated from dye study tests on the Savannah Harbor Model*
(May-June, 1963 Model Studies)

Station Location River Mile	Model Station No.	High Water Slack City of Savannah (%)	High Water Slack Savannah Beach (%)	Low Water Slack City of Savannah (%)	Low Water Slack Savannah Beach (%)	Median City of Savannah (%)	Median Savannah Beach (%)
Savannah River							
S-6	24-16	98	2	100	0	> 99	< 1
S-4	25-14	87	13	> 99	< 1	96	4
S-0	26- 7	69	31	> 99	< 1	99	1
Fields Cut							
-	8-13	> 99	< 1	98	2	99	1
Wright River							
W-4.5	9-12	94	6	96	4	94	6
W-0	12- 8	80	20	90	10	85	15
New River							
N-3.8	10-10	80	20	89	11	86	14
N-0	11- 9	31	69	91	9	57	43

Table No.D Cont.

PROPORTIONATE EFFECT OF SIMULATED SEWAGE DISCHARGES
FROM SAVANNAH BEACH AND THE CITY OF SAVANNAH
Calculated from dye study tests on
the Savannah Harbor Model*
(May-June, 1963 Model Studies)

Station Location River Mile	Model Station No.	High Water Slack City of Savannah (%)	High Water Slack Savannah Beach (%)	Low Water Slack City of Savannah (%)	Low Water Slack Savannah Beach (%)	Median City of Savannah (%)	Median Savannah Beach (%)
Calibogue Sound							
C-1	13-11	75	25	70	30	72	28
Elba Island Cut							
-	7-15	98	2	> 99	< 1	99	1
Coastal Waterway							
-	4-17	99	1	> 99	< 1	99	1
South Channel							
-	5- 6	14	86	96	4	77	23
Tybee River							
-	31-18	91	9	99	1	96	4

* Percent of the total simulated pollution from Savannah Beach and the city of Savannah, remaining throughout the Estuary at equilibrium after 50 tidal cycles, attributable to each of these two sources.

Residual dye readings reflect the effects of dilution; the time of travel and age of dye at each location was calculated from the model data; and all observed concentrations were reduced according to a time-dependent bacterial die-off rate for brackish water.

Table No. E

DISSOLVED OXYGEN (D.O. in mg/l)

August, 1963 Survey
Savannah River Estuary

Station Location River Mile	Lab. No.	Depth	No. of Samples	Arith. Average	Max.	Min.	% of Samples Below Critical Levels Below 5.0	Below 4.0	Below 3.0	Below 2.0	Below 1.0
S-28	11	5'	9	6.5	6.9	6.2	0	0	0	0	0
		15'	7	6.5	6.7	6.3	0	0	0	0	0
		28'	0	-	-	-	-	-	-	-	-
		Avg.	16	6.5			0	0	0	0	0
S-22	9	5'	11	6.4	7.2	5.5	0	0	0	0	0
		15'	11	6.4	7.3	5.5	0	0	0	0	0
		28'	6	6.0	6.6	5.3	0	0	0	0	0
		Avg.	28	6.3			0	0	0	0	0
S-19	8	5'	10	5.3	6.6	3.1	30	20	0	0	0
		15'	10	5.3	6.4	2.5	20	20	20	0	0
		28'	11	5.2	6.2	2.5	27	18	18	0	0
		Avg.	31	5.3			26	19	13	0	0
S-16	7	5'	25	3.1	5.5	1.1	84	68	52	24	0
		15'	26	3.1	5.2	1.2	92	62	54	19	0
		28'	24	2.9	5.0	0.7	92	62	50	33	4
		Avg.	75	3.0			89	64	52	25	1

Table No.E
cont.

DISSOLVED OXYGEN (D.O. in mg/l)

August, 1963 Survey
Savannah River Estuary

Station Location River Mile	Lab. No.	Depth	No. of Samples	Arith. Average	Max.	Min.	% of Samples Below Critical Levels Below 5.0	Below 4.0	Below 3.0	Below 2.0	Below 1.0
S-14	6	5'	26	2.3	4.4	0.8	100	88	77	38	12
		15'	26	2.3	4.2	0.5	100	88	69	42	19
		28'	25	1.8	3.6	0.3	100	100	84	68	28
		Avg.	77	2.1			100	92	77	49	20
S-11.5-0.5	5	5'	27	1.9	3.7	0.6	100	100	89	52	15
		15'	27	1.8	3.6	0.1	100	100	89	59	15
		28'	16	1.5	2.8	0.4	100	100	100	69	38
		Avg.	70	1.8			100	100	92	59	20
S-10	4	5'	27	2.0	3.6	0.8	100	100	89	59	7
		15'	28	1.4	3.0	0.5	100	100	96	46	7
		28'	26	1.6	2.8	0.6	100	100	100	69	12
		Avg.	81	1.8			100	100	95	58	9
S-5	3	5'	24	2.7	5.0	1.1	96	79	62	33	0
		15'	24	2.8	5.0	1.3	92	75	62	21	0
		28'	23	3.0	5.1	1.6	91	86	56	9	0
		Avg.	71	2.8			93	78	60	21	0

Table No. E
cont.

DISSOLVED OXYGEN (D.O. in mg/l)

August, 1963 Survey
Savannah River Estuary

Station Location River Mile	Lab. No.	Depth	No. of Samples	Arith. Average	Max.	Min.	% of Samples Below Critical Levels Below 5.0	Below 4.0	Below 3.0	Below 2.0	Below 1.0
S-2	2	5'	24	3.6	6.9	1.9	79	62	58	4	0
		15'	24	3.5	5.6	1.8	83	62	38	4	0
		28'	23	3.8	5.4	2.3	83	56	26	0	0
		Avg.	71	3.6			82	61	41	3	0
S--2	1	5'	22	4.4	6.6	1.7	59	32	23	4	0
		15'	22	4.5	6.2	2.7	59	32	4	0	0
		28'	21	4.8	6.3	3.2	57	10	0	0	0
		Avg.	65	4.6			58	25	9	2	0

TEMPERATURE IN °C. Table No.F

August, 1963 Survey
Savannah River Estuary

Station Location River Mile	Lab. No.	Depth	No. of Samples	Field Observations Arith. Average	Max.	Min.
Savannah River						
S-28	11	5'	9	26.9	28.0	25.5
		15'	7	26.9	28.0	26.0
		28'	1	25.5	-	-
		Avg.		26.9		
S-22	9	5'	11	27.2	28.0	26.0
		15'	11	27.0	28.0	26.0
		28'	6	26.8	27.0	26.5
		Avg.		27.0		
S-19	8	5'	11	27.3	28.0	26.0
		15'	10	27.5	28.5	27.0
		28'	11	27.4	28.5	26.5
		Avg.		27.4		
S-16	7	5'	26	27.5	29.0	27.0
		15'	26	27.5	29.0	27.0
		28'	26	27.4	29.0	24.5
		Avg.		27.5		
S-14	6	5'	26	27.8	29.0	27.0
		15'	26	27.7	29.0	27.0
		28'	26	27.6	29.5	25.0
		Avg.		27.7		

Table No.F cont.

TEMPERATURE IN °C.

August, 1963 Survey
Savannah River Estuary

Station Location			No. of Samples	Field Observations		
River Mile	Lab. No.	Depth		Arith. Average	Max.	Min.
Savannah River, cont.						
S-10	4	5'	28	28.5	29.5	27.0
		15'	28	28.5	30.0	27.0
		28'	28	28.0	29.5	26.5
		Avg.		28.3		
S-5	3	5'	31	28.5	30.0	27.0
		15'	25	28.5	29.5	27.5
		28'	30	28.0	29.5	27.0
		Avg.		28.3		
S-2	2	5'	31	28.5	29.5	27.0
		15'	25	28.5	29.0	27.5
		28'	31	28.0	29.0	27.0
		Avg.		28.3		
S--2	1	5'	31	28.5	29.5	27.0
		15'	25	28.5	29.5	27.5
		28'	31	28.0	29.0	27.0
		Avg.		28.3		
S-11.5-0.5	(5)	5'	27	28.0	29.5	27.0
		15'	17	28.0	29.5	27.0
		28'	16	28.0	29.0	27.0
		Avg.		28.0		

Table No. F cont.

TEMPERATURE IN °C.

August, 1963 Survey
Savannah River Estuary

Station Location			No. of Samples	Field Observations		
River Mile	Lab. No.	Depth		Arith. Average	Max.	Min.
Wright River						
W-4.5	15	5'	26	28.5	30.5	27.5
		15'	10	29.2	30.0	28.0
		Avg.		28.7		
W-2.8	14	5'	26	28.4	29.5	27.5
		15'	11	28.8	29.5	28.0
		Avg.		28.5		
W-1.9	13	5'	28	28.3	29.5	27.5
		15'	12	28.6	29.5	28.0
		Avg.		28.4		
W-0.0	12	5'	26	28.2	29.5	27.0
		15'	13	28.5	29.5	27.5
		Avg.		28.3		
New River						
N-6.2	19	5'	30	28.7	30.5	27.0
		15'	1	29.0	-	-
		28'	23	28.8	30.5	27.5
		Avg.		28.8		
N-4.0	18	5'	30	28.4	30.5	27.0
		15'	9	28.4	30.5	27.0
		28'	13	28.6	30.0	27.5
		Avg.		28.5		

Table No. F cont.

TEMPERATURE IN °C.

August, 1963 Survey
Savannah River Estuary

Station Location			No. of Samples	Field Observations		
River Mile	Lab. No.	Depth		Arith. Average	Max.	Min.
New River, cont.						
N-3.8	17	5'	30	28.5	30.5	27.0
		15'	-	-	-	-
		28'	24	28.5	30.5	27.0
		Avg.		28.5		
N-0.0	16	5'	29	28.4	30.0	27.0
		15'	4	29.2	30.0	27.5
		28'	20	28.1	29.5	27.0
		Avg.		28.2		
Cooper River - Calibogue Sound						
C-5	22	5'	23	29.2	31.5	27.5
		28'	23	29.4	31.5	27.5
		Avg.		29.3		
C-2	21	5'	23	29.1	31.5	27.5
		28'	23	29.1	31.0	27.5
		Avg.		29.1		
C-0	20	5'	23	28.4	30.5	28.0
		28'	23	28.8	30.5	27.5
		Avg.		28.6		

pH

Table No. G

August, 1963 Survey
Savannah River Estuary

Station Location			No. of Samples	Field Observations		
River Mile	Lab. No.	Depth		Arith. Average	Max.	Min.
Savannah River						
S-28	11	5'	4	6.6	6.8	6.4
		15'	2	6.5	6.6	6.3
		28'	1	6.2	6.2	6.2
		Avg.		6.6		
S-22	9	5'	6	6.4	6.8	6.8
		15'	6	6.4	6.6	6.3
		28'	3	6.5	6.8	6.2
		Avg.		6.4		
S-19	8	5'	6	6.7	6.8	6.6
		15'	5	6.6	6.8	6.3
		28'	6	6.6	6.8	6.4
S-16	7	5'	25	6.2	6.8	5.0
		15'	25	6.2	6.8	5.0
		28'	25	6.2	6.6	5.0
		Avg.		6.2		
S-14	6	5'	25	6.2	6.7	5.2
		15'	24	6.2	6.9	5.4
		28'	24	6.3	6.8	5.6
		Avg.		6.2		

pH

Table No. 6 cont.

August, 1963 Survey
Savannah River Estuary

Station Location			No. of	Field Observations		
River Mile	Lab. No.	Depth	Samples	Arith. Average	Max.	Min.
Savannah River, cont.						
S-10	4	5'	28	6.4	7.0	5.6
		15'	28	6.4	7.2	5.6
		28'	28	6.5	7.2	5.1
		Avg.		6.4		
S-5	3	5'	24	6.8	7.2	6.2
		15'	24	6.8	7.6	6.0
		28'	24	7.0	7.6	6.4
		Avg.		6.9		
S-2	2	5'	25	7.0	7.6	6.2
		15'	25	7.1	7.6	6.2
		28'	25	7.2	7.6	6.4
		Avg.		7.1		
S--2	1	5'	25	7.3	7.7	6.4
		15'	25	7.2	7.6	6.4
		28'	25	7.4	7.6	6.4
		Avg.		7.3		
S-11.5-0.5	(5)	5'	27	6.4	7.0	5.8
		15'	26	6.4	7.0	5.8
		28'	16	6.3	6.9	4.2
		Avg.		6.4		

COLIFORM BACTERIA (Mean of MPN/100 ml) Table No. H

Summary of CROSS SECTION Data
Oct.-Nov., 1962 Preliminary Survey
Savannah River Estuary

River Mile	TOTAL COLIFORMS				FECAL COLIFORMS			
	Ga. Side 5' D.	Center Channel 5' D.	S.C. Side 5'D.	Center Channel 28' D.	Ga. Side 5' D.	Center Channel 5' D.	S.C. Side 5'D.	Center Channel 28' D.
20	9,500	10,100	8,500	11,600	1,770	2,330	1,120	2,130
18	13,880	10,050	8,220	-	2,860	1,700	874	-
16	26,500	> 45,400	26,500	8,150	5,180	3,020	3,070	2,760
14	38,100	38,100	34,800	8,610	5,940	9,980	8,730	3,130
10	8,200	15,850	14,100	3,380	2,210	3,010	3,650	980
8	13,720	8,940	6,170	650	3,670	2,440	1,930	190
6	6,550	7,240	5,160	460	2,450	1,539	2,140	170
2	4,900	7,950	3,250	160	800	1,110	920	50
0	1,420	4,900	1,560	80	520	2,300	520	50

Table No. I

DISSOLVED OXYGEN (Mean of mg/l and % Saturation)

Summary of CROSS SECTION Data
Oct.-Nov., 1962 Preliminary Survey
Savannah River Estuary

River Mile	D. O. (mg/l) Ga. Side 5' D.	Center Channel 5' D.	S.C. Side 5'D.	Center Channel 28' D.	D. O. (% Sat.) Ga. Side 5' D.	Center Channel 5' D.	S.C. Side 5' D.	Center Channel 28' D.
28	9.1	-	9.0	-	88	-	88	-
23	8.3	8.3	8.3	-	86	86	86	-
22	6.6	7.4	7.4	-	70	81	81	-
20	7.2	7.2	7.2	7.2	74	75	73	74
18	7.3	7.3	7.5	6.7	72	72	74	67
16	4.9	5.0	5.1	3.7	52	53	54	40
14	4.1	4.2	4.3	3.6	45	45	46	41
10	4.4	4.6	4.6	4.7	49	51	52	57
8	4.9	4.8	4.6	5.2	54	54	52	64
6	5.0	5.1	5.1	5.6	57	58	59	70
2	6.1	6.0	6.2	6.4	72	71	73	81
0	6.6	6.3	6.4	6.5	79	76	77	83

Table No. J

SAVANNAH RIVER DISCHARGE RECORDS
at USGS Gage near Clyo, Ga. (River Mile S-65)

August, 1963 Survey
Savannah River Estuary

Discharge During 1963 Survey

Day	Date	Mean Daily Discharge (cfs)	Day	Date	Mean Daily Discharge (cfs)
	8/6/63	11,900		8/16/63	7,820
	7	9,900		17	8,500
	8	9,340	Sunday	18	8,980
	9	10,500		19	8,740
	10	10,900		20	8,040
Sunday	11	10,600		21	7,820
	12	9,760		22	8,260
	13	8,500		23	9,340
	14	7,710		24	10,200
	15	7,490			
				Avg.	9,170
				Max.	11,900
				Min.	7,490

Recent Water Year Records

Water Year	Mean	Max.	Min.
1962-1963	12,222	29,200	6,960
1961-1962	12,050	28,200	6,160
1960-1961	11,770	34,300	6,610
1959-1960	16,540	40,300	6,810
1958-1959	8,915	25,500	5,760

Long Term Records

30-yr. Avg.	11,360	
Max.	270,000	(Oct. 6, 1929)
Min.	1,950	(Sept. 27, 1931)

Other Records

Mean during 1962 Prelim. Survey	7,180
Max. " " " "	7,380
Min. " " " "	6,960

Discharge for Savannah Harbor Model Study = 7,000

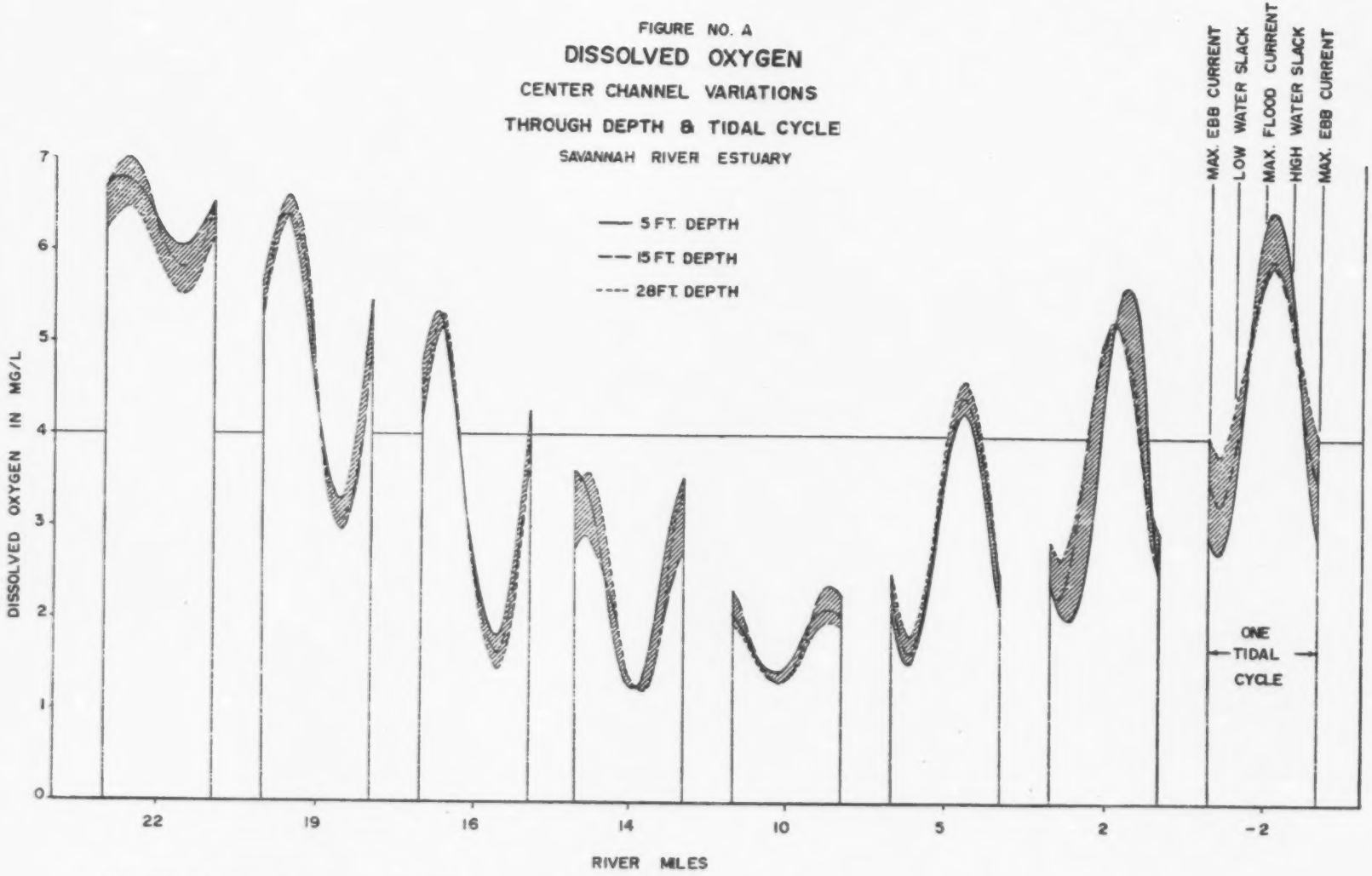
FIGURE NO. A

DISSOLVED OXYGEN

CENTER CHANNEL VARIATIONS

THROUGH DEPTH & TIDAL CYCLE

SAVANNAH RIVER ESTUARY



EACH CYCLIC PROFILE STARTS AT THE TIME MAXIMUM EBB CURRENT OCCURS AT THE MOUTH.

FIGURE NO. 8

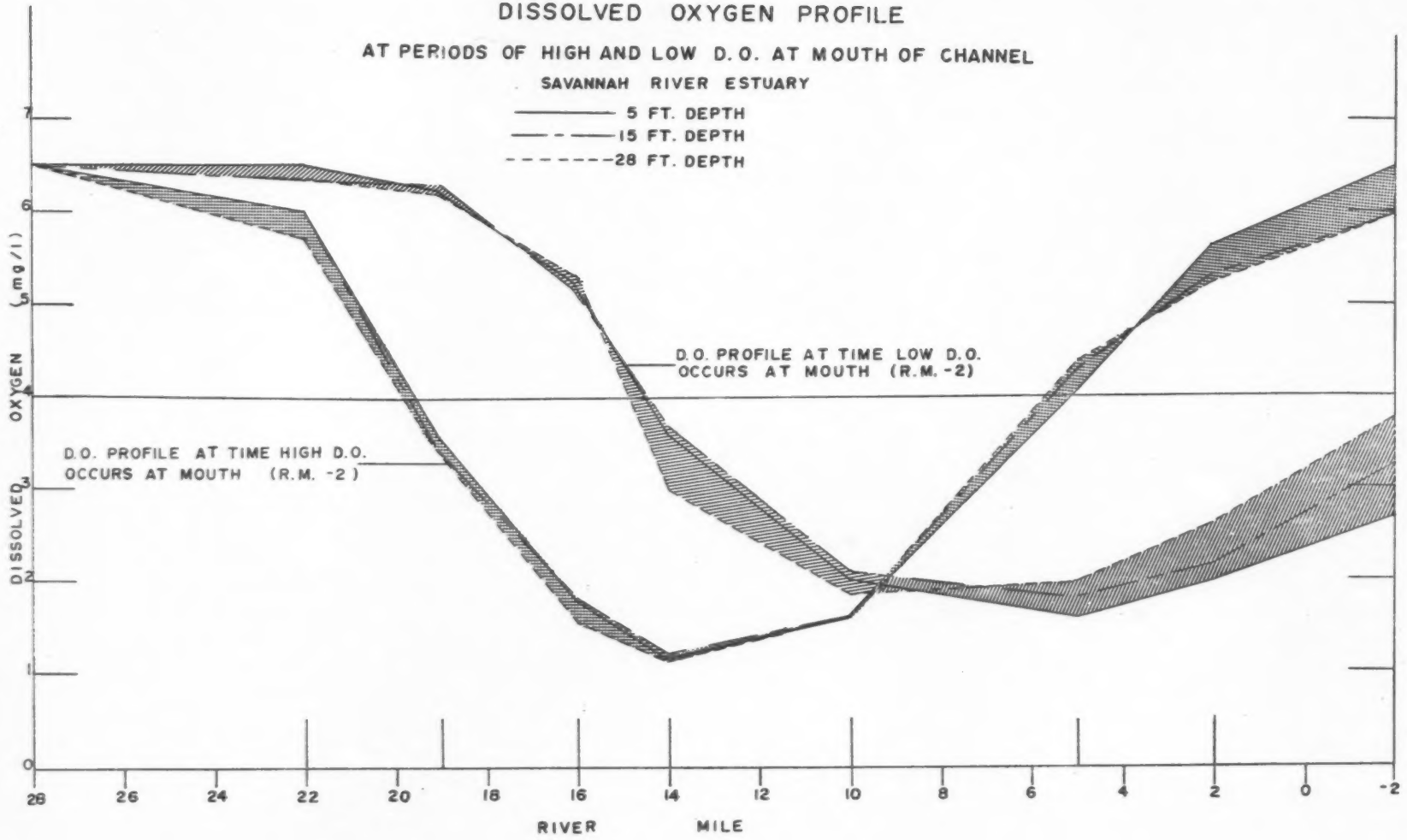

DISSOLVED OXYGEN PROFILE
AT PERIODS OF HIGH AND LOW D.O. AT MOUTH OF CHANNEL
SAVANNAH RIVER ESTUARY
5 FT. DEPTH
15 FT. DEPTH
28 FT. DEPTH
D.O. PROFILE AT TIME LOW D.O. OCCURS AT MOUTH (R.M. -2)
D.O. PROFILE AT TIME HIGH D.O. OCCURS AT MOUTH (R.M. -2)
DISSOLVED OXYGEN (mg/l)
0
1
2
3
4
5
6
7
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
-2
RIVER MILE

FIGURE NO. C

STATION IDENTIFICATION MAP

SURVEY & DYE STUDY STATIONS

SAVANNAH RIVER ESTUARY

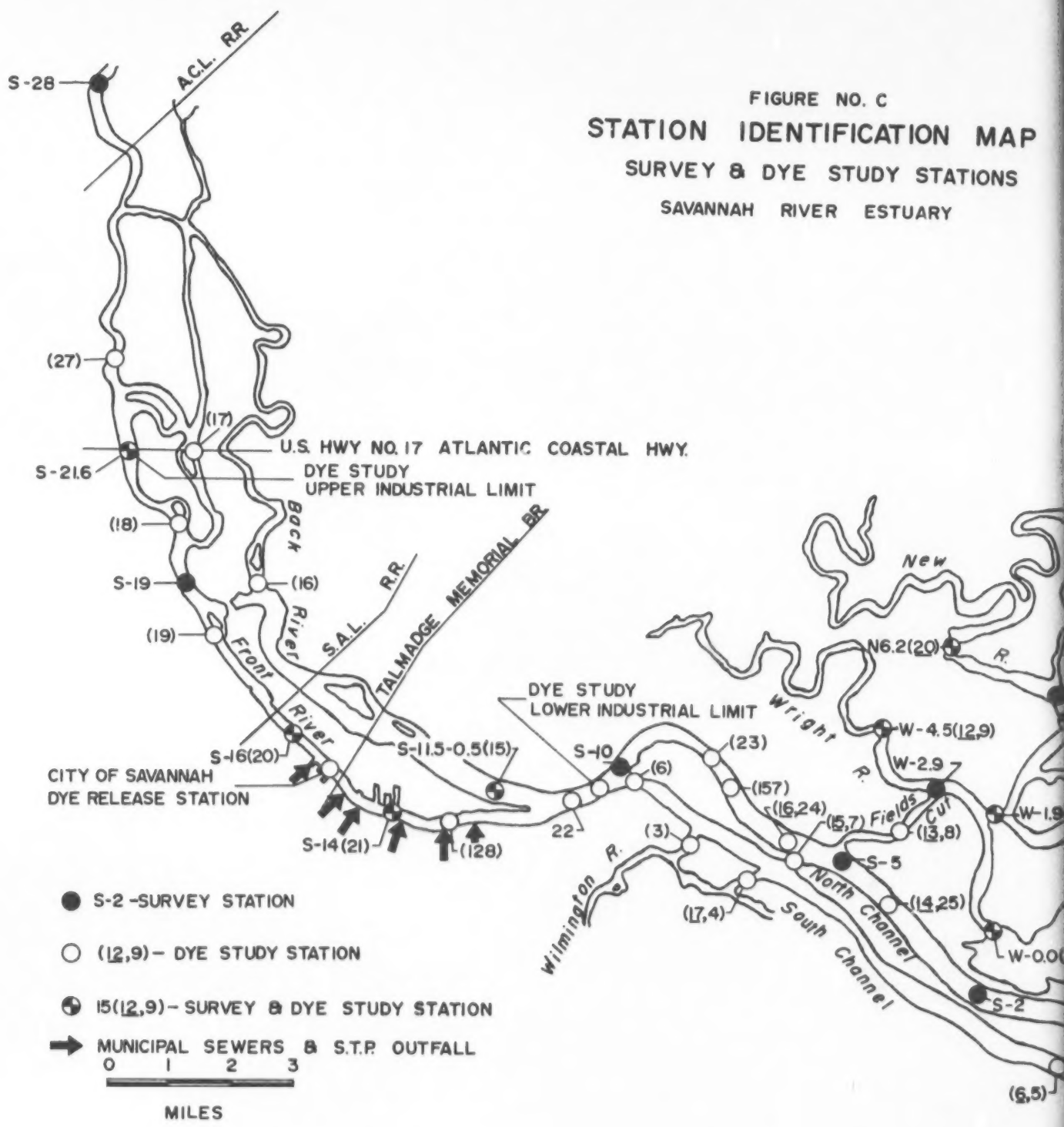


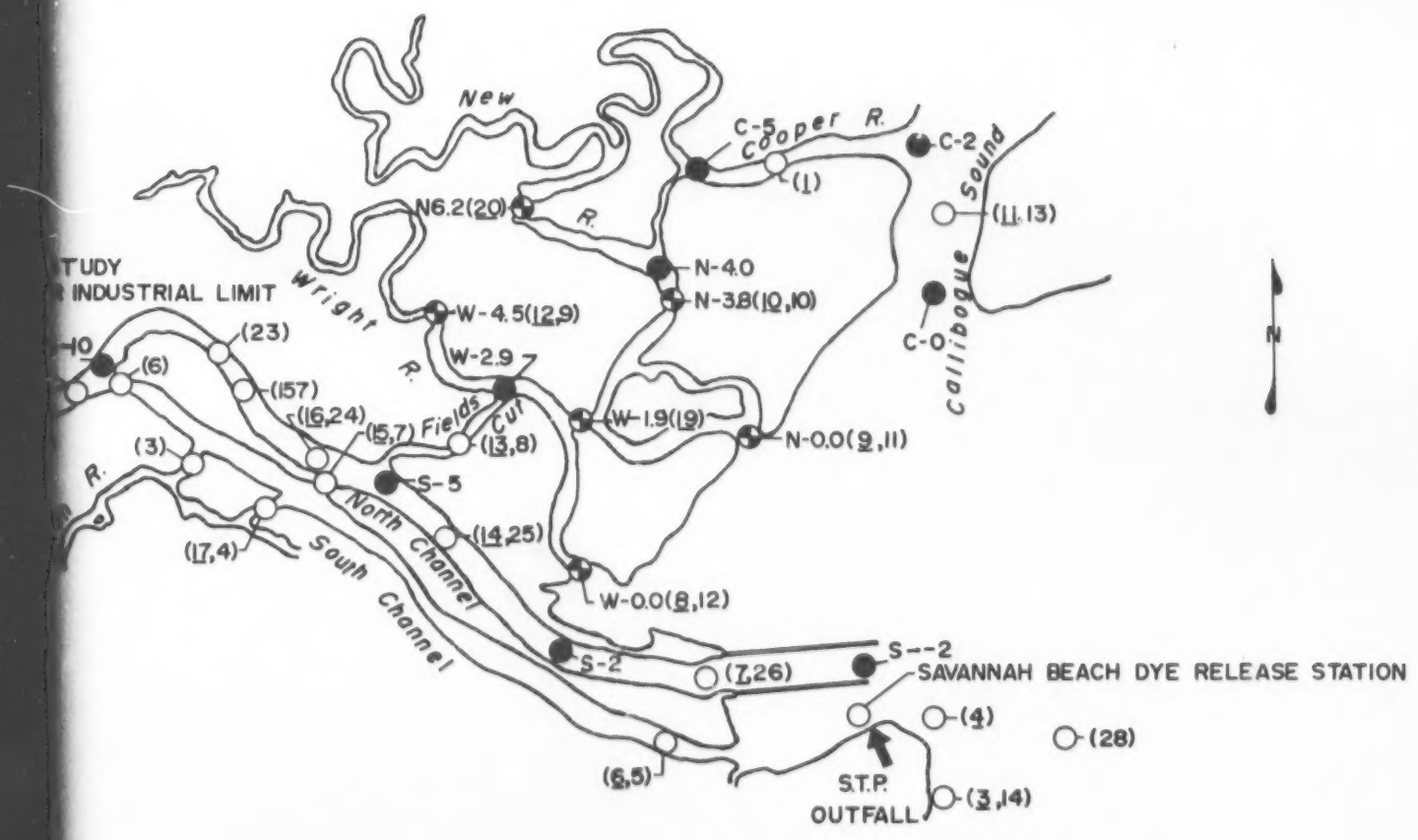
FIGURE NO. C

STATION IDENTIFICATION MAP

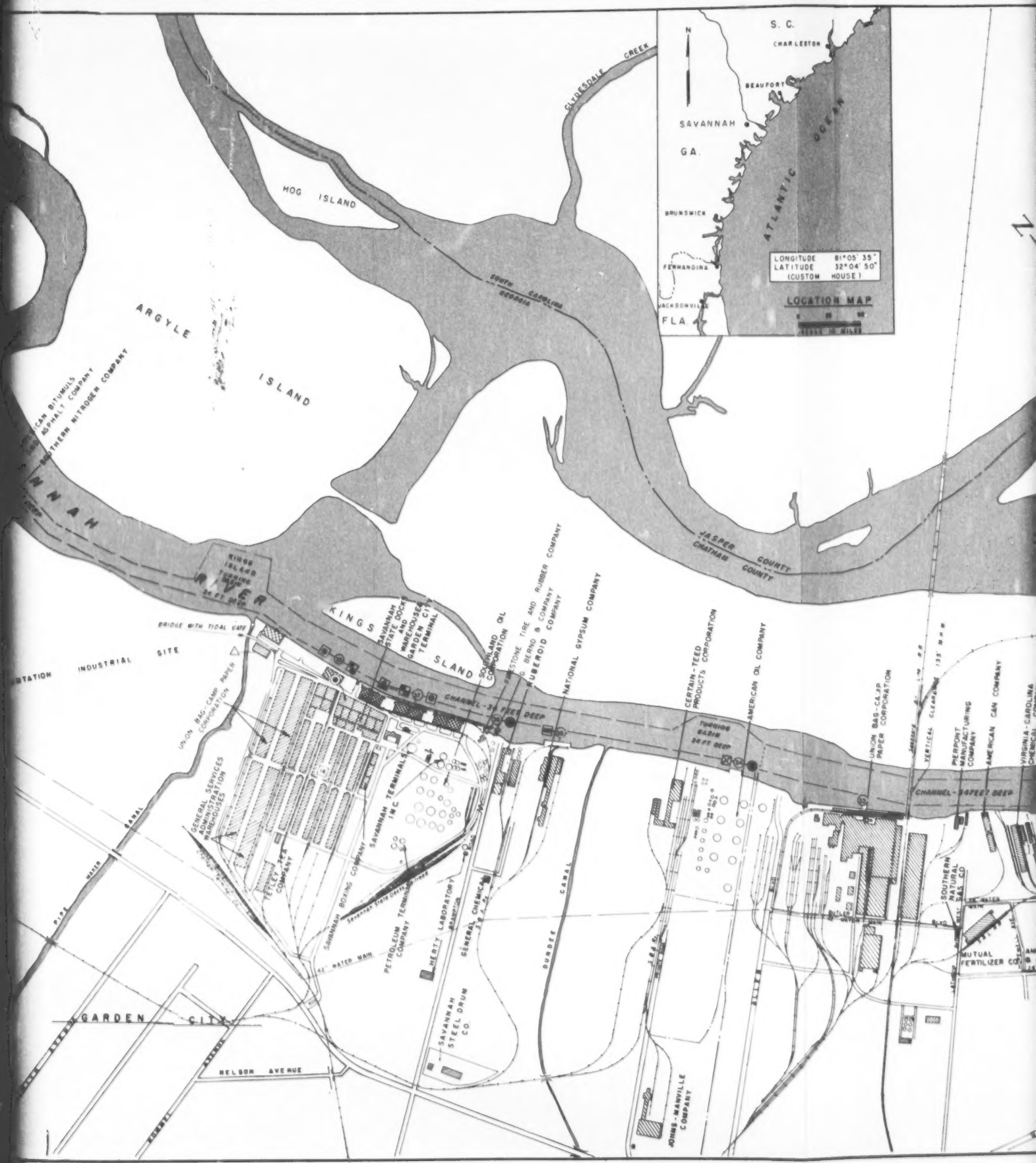
SURVEY & DYE STUDY STATIONS

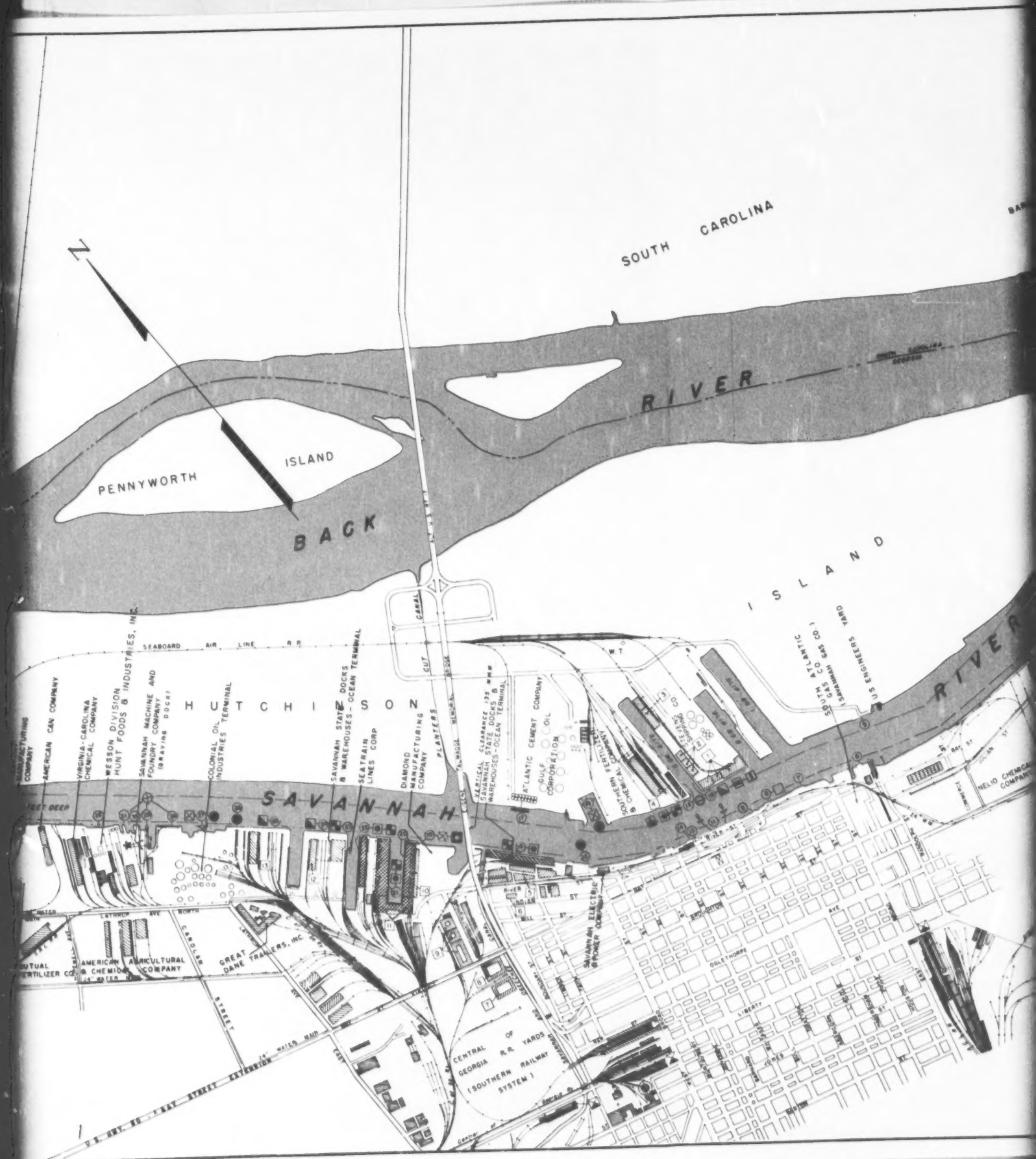
SAVANNAH RIVER ESTUARY

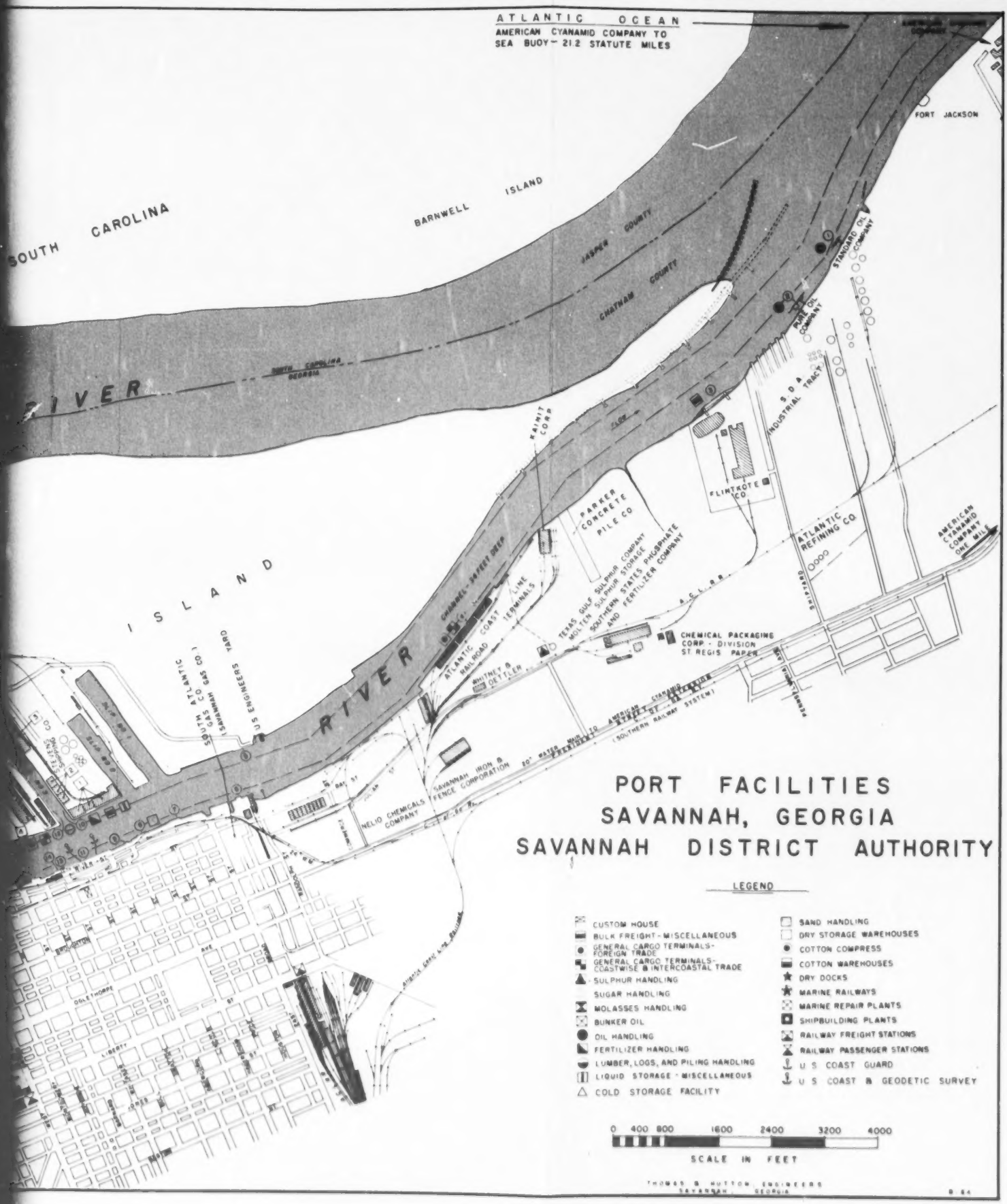
STAL HWY.



ONSLOW ISLAND
CARBIDE CORPORATION (SITE)
MIDDLE RIVER
SAVANNAH ELECTRIC & POWER CO.
ATLANTIC CREOSOTING COMPANY
SAVANNAH SUGAR REFINING CORPORATION
CONTINENTAL CAN COMPANY
SAVANNAH RIVER ORE & CHEMICAL COMPANY
PORT WENTWORTH
WHITEHALL PLANTATION
RAILROAD OVERPASS
SAVANNAH INDUSTRIAL AND DOMESTIC WATER SUPPLY FILTRATION PLANT
SOUTHERN NITROGEN COMPANY
SAVANNAH AND ATLANTA RAILWAY (SOUTHERN RAILWAY SYSTEM)
ATLANTIC COAST LINE RAILROAD
SEABOARD AIR LINE RAILROAD
SAVANNAH AND ATLANTA RAILROAD
TRAVIS FIELD
SAVANNAH MUNICIPAL AIRPORT
TO MUNICIPAL AIRPORT
1/2 MILE
42" WATER MAIN
40" WATER MAIN
24" WATER MAIN
U.S. HWY. 17
STATE HWY. 21


S. C.
CHARLESTON
BEAUFORT
SAVANNAH
GA.
ATLANTIC OCEAN
BRUNSWICK
FERNANDINA
JACKSONVILLE
FLA.
LONGITUDE 81°05' 35"
LATITUDE 32°04' 50"
(CUSTOM HOUSE)
LOCATION MAP
HOG ISLAND
ARGYLE ISLAND
SOUTH CAROLINA
GEORGIA
JASPER COUNTY
CHATHAM COUNTY
KINGS ISLAND
KINGS ISLAND TURNING BASIN 30 FT. DEEP
BRIDGE WITH TIDAL GATE
INDUSTRIAL SITE
CHANNEL - 30 FEET DEEP
TURNING BASIN 30 FT. DEEP
CHANNEL - 30 FEET DEEP
SAVANNAH STATE DOCKS WAREHOUSES GARDEN CITY TERMINAL
SOUTHLAND OIL CORPORATION
FIRESTONE TIRE AND RUBBER COMPANY
U. S. BERND & COMPANY
RUBEROID COMPANY
NATIONAL GYPSUM COMPANY
CERTAIN-TEED PRODUCTS CORPORATION
AMERICAN OIL COMPANY
UNION BAG-CAMP PAPER CORPORATION
PERPONT MANUFACTURING COMPANY
AMERICAN CAN COMPANY
VIRGINIA-CAROLINA CHEMICAL
UNION BAG-CAMP PAPER CORPORATION
GENERAL SERVICES ADMINISTRATION WAREHOUSES
SAVANNAH TERMINALS INC
TELEY CO.
SAVANNAH BOXING COMPANY
SAVANNAH STATE DOCKS TERMINAL
PETROLEUM TERMINAL COMPANY
MERITY LABORATORY
GENERAL CHEMICAL CO.
DUNDEE CANAL
SOUTHERN NATURAL GAS CO.
MUTUAL FERTILIZER CO.
SAVANNAH STEEL DRUM CO.
JOHNS-MANVILLE COMPANY
GARDEN CITY
BELSON AVENUE
ARGYLE CANAL
PIPE
WATER
42" WATER MAIN


N
SOUTH CAROLINA
RIVER
PENNYWORTH ISLAND
BACK
ISLAND
RIVER
SEABOARD AIR LINE R.R.
GUT CANAL
H U T C H I S O N
SAVANNAH
AMERICAN CAN COMPANY
VIRGINIA-CAROLINA CHEMICAL COMPANY
WESSON DIVISION HUNT FOODS & INDUSTRIES, INC.
SAVANNAH MACHINE AND FOUNDRY COMPANY
COLONIAL OIL INDUSTRIES TERMINAL
SAVANNAH STATE DOCKS & WAREHOUSES - OCEAN TERMINAL
SEATRAIN LINES CORP
DIAMOND MANUFACTURING COMPANY
PLANTERS
ATLANTIC CEMENT COMPANY
GULF OIL CORPORATION
SOUTHERN FERTILIZER & CHEMICAL CO.
SOUTH ATLANTIC GAS CO.
SAVANNAH TUGBOAT
U.S. ENGINEERS YARD
NELIO CHEMICAL COMPANY
LATHROP AVE
AMERICAN AGRICULTURAL & CHEMICAL COMPANY
GREAT DANE TRAILERS, INC
SAVANNAH ELECTRIC & POWER COMPANY
CENTRAL OF GEORGIA R.R. YARDS
(SOUTHERN RAILWAY SYSTEM)
OGLETHORPE
LIBERTY
JONES
BAY ST
BROUGHTON
BARNARD
DRAYTON
ABERCORN
HOUSTON
HALL
MONTGOMERY
JEFFERSON
BULL
WHITAKER
EAST BROAD
WEST BROAD
CAROLINA
EXTENSION
WATER MAIN



PORT FACILITIES
SAVANNAH, GEORGIA
SAVANNAH DISTRICT AUTHORITY

LEGEND

- CUSTOM HOUSE
- BULK FREIGHT - MISCELLANEOUS
- GENERAL CARGO TERMINALS - FOREIGN TRADE
- GENERAL CARGO TERMINALS - COASTWISE & INTERCOASTAL TRADE
- SULPHUR HANDLING
- SUGAR HANDLING
- MOLASSES HANDLING
- BUNKER OIL
- OIL HANDLING
- FERTILIZER HANDLING
- LUMBER, LOGS, AND PILING HANDLING
- LIQUID STORAGE - MISCELLANEOUS
- COLD STORAGE FACILITY
- SAND HANDLING
- DRY STORAGE WAREHOUSES
- COTTON COMPRESS
- COTTON WAREHOUSES
- DRY DOCKS
- MARINE RAILWAYS
- MARINE REPAIR PLANTS
- SHIPBUILDING PLANTS
- RAILWAY FREIGHT STATIONS
- RAILWAY PASSENGER STATIONS
- U S COAST GUARD
- U S COAST & GEODETIC SURVEY

0 400 800 1600 2400 3200 4000

SCALE IN FEET

THOMAS B. HUTTON, ENGINEERS
SAVANNAH, GEORGIA

D 64

PORT AND HARBOR FACILITIES
SAVANNAH, GEORGIA, U.S.A.

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For port and industrial information contact

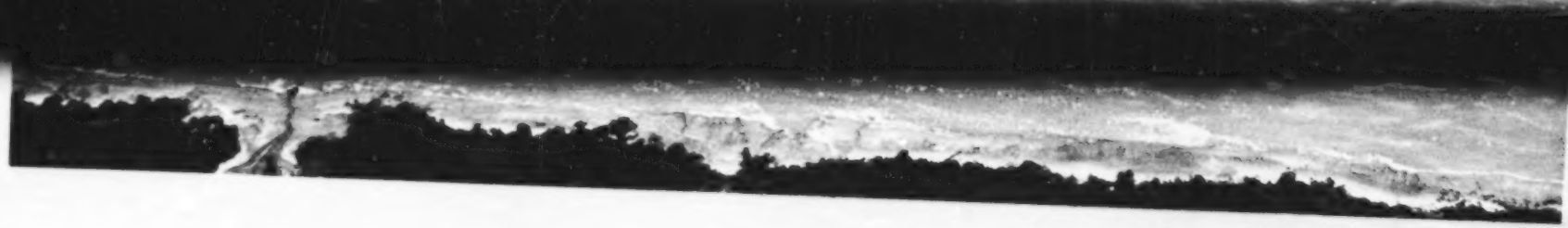
SAVANNAH DISTRICT AUTHORITY
42 Bay Street East (P. O. Box 768)
Savannah, Georgia

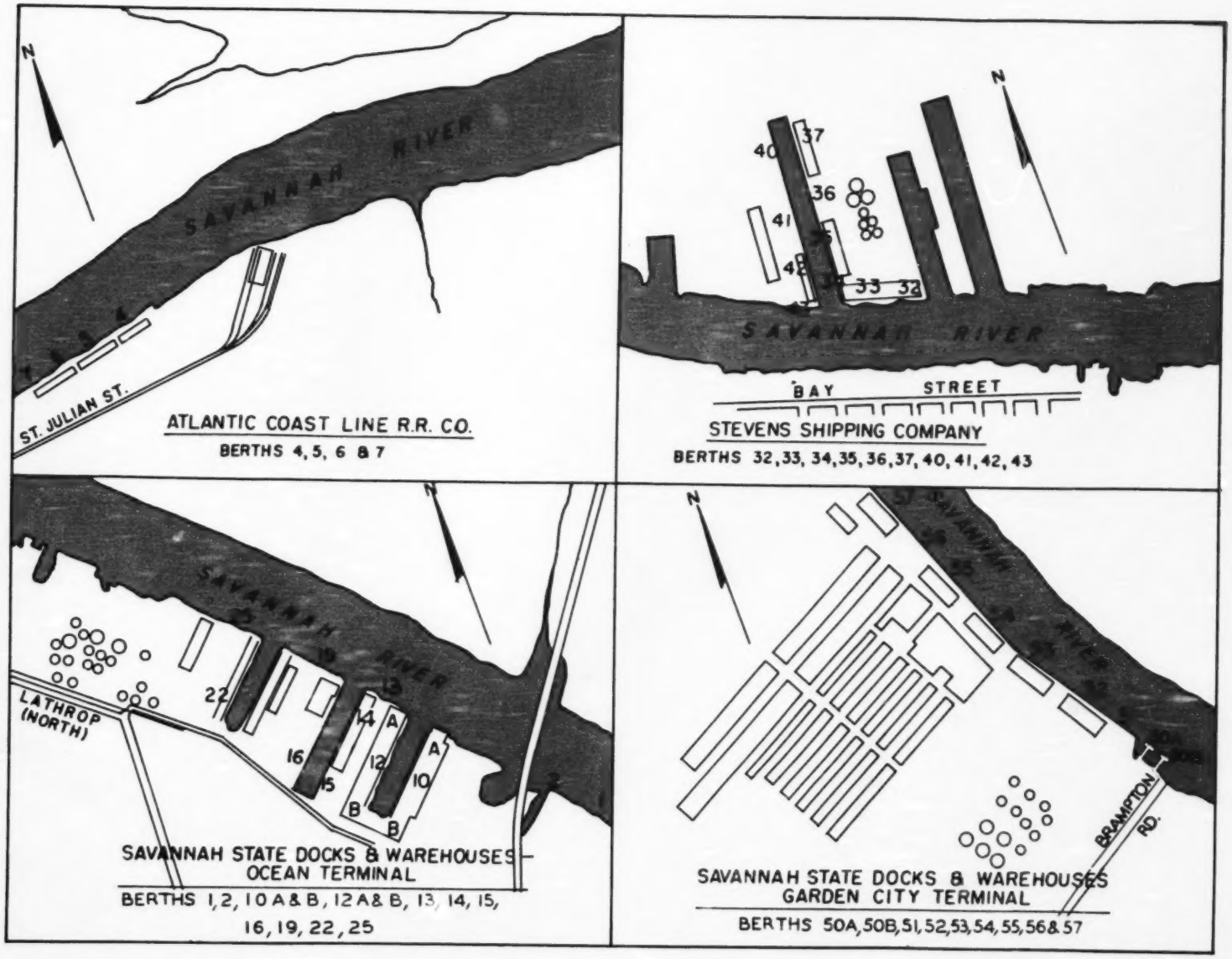
LIST OF PIERS, WHARVES AND DOCKS

No. Circle Ref.	Name of Facility
①	Standard Oil Company Wharf
2	Pure Oil Company, Docks A and B
3	The Flintkote Company Wharf
4	Atlantic Coast Line Railroad Company Wharf (Berths 4, 5, 6, and 7)
5	Corps of Engineers, U. S. Army Hutchinson Island Yard Wharf
6	Merry Brothers Brick and Tile Company Wharf
7	Atlantic Towing Company Towboat Wharf
8	Fitzgerald-Montgomery Sand Corporation Dock
9	Savannah District Authority Wharf
10	Stevens Shipping Company Terminal, Pier 3 (Berths 32, 33, 34, 35, 36, and 37)
11	Savannah District Authority Wharf
12	Stevens Shipping Company Terminal, Pier 4 (Berths 40, 41, 42, and 43)
13	Bull Street Wharf, City of Savannah
14	Corps of Engineers, U. S. Army, Bull Street Wharf
15	Gulf Oil Corporation Slip
16	Savannah Electric and Power Company Fuel Dock
17	Atlantic Cement Company, Inc. Wharf
18	Savannah State Docks and Warehouses — Ocean Terminal (Berths 1 and 2)
19	Diamond Manufacturing Company, Inc. Wharf
20	Savannah State Docks and Warehouses — Ocean Terminal (Berths 10a and 10b)
21	Savannah State Docks and Warehouses — Ocean Terminal (Berths 12a and 12b)
22	Savannah State Docks and Warehouses — Ocean Terminal (Berths 13, 14, and 15)
23	Savannah State Docks and Warehouses — Ocean Terminal (Berth 16)
24	Savannah State Docks and Warehouses — Ocean Terminal (Berth 19)
25	Savannah State Docks and Warehouses — Ocean Terminal (Berth 25)
26	Colonial Oil Industries, Barge Wharf
27	Colonial Oil Industries, Oil Pier
28	Savannah Machine and Foundry Company — Wharf
29	Savannah Machine and Foundry Company — Wet Basin Pier
30	Savannah Machine and Foundry Company — Center Pier
31	Savannah Machine and Foundry Company — Upper Pier
32	Wesson Division, Hunt Foods and Industries, Inc.
33	Union Bag-Camp Paper Corporation Wharf
34	American Oil Company Wharf
35	National Gypsum Company Wharf
36	Savannah State Docks — Garden City Terminal (T head Piers 50a and 50b)
37	Savannah State Docks — Garden City Terminal (Berths 51, 52, 53, and 54)
38	Savannah State Docks — Garden City Terminal (Berths 55, 56, and 57)
39	American Bitumuls and Asphalt Company Wharf
40	Savannah Sugar Refining Corporation Liquid Sugar Dock
41	Savannah Sugar Refining Corporation Wharf
42	Atlantic Creosoting Company Wharf
43	Savannah Electric and Power Company, Port Wentworth Station Oil Dock
44	Continental Can Company, Incorporated Wharf

LIST OF STORAGE WAREHOUSES

Square Ref. No.	Name of Facility
1	Stevens Shipping Company Warehouses 2 and 3
2	Stevens Shipping Company Warehouses 5 and 6
3	Stevens Shipping Company Warehouses 8 and 9
4	Stevens Shipping Company Warehouse 4
5	Coastal Bonded Warehouse
6	Colonial Ice Company
7	Southeastern Warehouse and Storage Company
8	Savannah Bonded Warehouse and Transfer Company
9	Central of Georgia Railway Warehouses
10	Savannah State Docks and Warehouses — Ocean Terminal — City Shed
11	Savannah State Docks and Warehouses — Ocean Terminal — Headhouse
12	Savannah Lighterage and Transfer Company, Ocean Terminal Warehouse 15
13	Savannah Lighterage and Transfer Company, Ocean Terminal Warehouse 9
14	Savannah State Docks and Warehouses, Garden City Terminal Warehouses




N
SAVANNAH RIVER
ST. JULIAN ST.
ATLANTIC COAST LINE R.R. CO.
BERTHS 4, 5, 6 & 7
N
40
37
36
41
42
33
32
SAVANNAH RIVER
BAY STREET
STEVENS SHIPPING COMPANY
BERTHS 32, 33, 34, 35, 36, 37, 40, 41, 42, 43
N
SAVANNAH RIVER
LATHROP (NORTH)
22
16
15
14
13
12
A
A
10
B
B
SAVANNAH STATE DOCKS & WAREHOUSES — OCEAN TERMINAL
BERTHS 1, 2, 10 A & B, 12 A & B, 13, 14, 15, 16, 19, 22, 25
N
SAVANNAH RIVER
BRAMPTON RD.
SAVANNAH STATE DOCKS & WAREHOUSES
GARDEN CITY TERMINAL
BERTHS 50A, 50B, 51, 52, 53, 54, 55, 56 & 57